# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 08-248317
(43)Date of publication of application : 27.09.1996

(51)Int.Cl. G02B 15/16
G02B 13/18

(21)Application number : 07-079399
(22)Date of filing : 13.03.1995

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## (54) ZOOM LENS

(57)Abstract:

PURPOSE: To provide a compact zoom lens having well compensated chromatic aberration by compensating the variation of the position of an image plane at the time of power variation due to the movement of a second lens group by using a partial lens in a third lens group or a fourth lens group and satisfying a specified condition.

CONSTITUTION: This zoom lens is a lens system for compensating the variation of the position of an image plane at the time of power variation due to the movement of a second negative lens group by using a part of lenses in a third lens group or a fourth lens group. The conditional relations: (1) $0.25 < 1/(\nu d)1n < 0.04$, (2) $0.005 < (\Delta\theta gd)1n < 0.02$, (3) $0 < 1/(\nu d)1p < 0.0166$ are satisfied. In the relations, $\Delta\theta gd$ is the difference of ordinates from a line connecting K7 to F2 on the graph of $\theta gd - \nu d$ by representing the Abbe number of glass for a d-line by $\nu d$ and a partial dispersion ratio for a Lg line and the d-line by $\theta gd$, $(\Delta\theta gd)1n$, is the average value of $\Delta\theta gd$ of glass used for a negative lens composing the first positive lens group and $(\nu d)1p$, $(\nu d)1n$ are the average values of $\nu d$ of glass used for a positive lens and a negative lenses composing the first lens group.

LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other

than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

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CLAIMS

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[Claim(s)]

[Claim 1] The 1st lens group which has forward refractive power sequentially from a body side, and the 2nd lens group which moves in accordance with an optical axis on the occasion of zooming with negative refractive power, and carries out a variable power operation, It consists of the 3rd lens group with forward refractive power, and the 4th lens group of forward refractive power. The zoom lens which is satisfied with the lens system which amended fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses in said 3rd lens group, said 4th lens group, or these lens group of the following conditions (1), (2), and (3).

(1) 0.25 -- < -- 1/(nud) 1 -- n< 0.04 (2) -0.005<(deltathetagd) 1 -- n< 0.02 (3) 0 -- < -- 1/(nud)1p<0.0166, however deltathetagd -- the Abbe number of d line of ** material -- nud ** -- it carrying out and the partial dispersion ratio to g line and d line thetagd-nud when referred to as thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) The average of deltathetagd of the ** material used for the negative lens which constitutes the 1n of the 1st lens groups, and 1 (nud)p and 1 (nud)n are nud of the ** material used for the positive lens and negative lens which constitute the 1st lens group, respectively. It is the average.

[Claim 2] The 1st lens group which has forward refractive power sequentially from a body side, and the 2nd lens group which moves in accordance with an optical axis with negative refractive power in the case of zooming, and carries out a variable power operation, It consists of the 3rd lens group with forward refractive power, and the 4th lens group with forward refractive power. The zoom lens which is satisfied with the lens system which amends fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses of

said 3rd lens group, said 4th lens group, or these lens group of the following conditions (4), (5), (6), and (7).

(4) 0.014<1/(nud)2n<0.017 (5) -0.01<(deltathetagd)2n<0.01 (6) 0.030<1/(nud)2p (7) 0.015<(deltathetagd) 2p, however deltathetagd the Abbe number of d line of ** material nud thetagd-nud when carrying out and setting the partial dispersion ratio to g line and d line to thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) The average of deltathetagd of the ** material used for the positive lens and negative lens which constitute the 2nd lens group 2p and 2 (deltathetagd)n, respectively, and 2 (nud)p and 2 (nud)n are nud of the ** material used for the positive lens and negative lens which constitute the 2nd lens group, respectively. It is the average.

[Claim 3] The 1st lens group which has forward refractive power sequentially from a body side, and the 2nd lens group which moves in accordance with an optical axis on the occasion of zooming with negative refractive power, and carries out a variable power operation, It consists of the 3rd lens group with forward refractive power, and the 4th lens group with forward refractive power. The zoom lens which is satisfied with the lens system which amends fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses of said 3rd lens group, said 4th lens group, or these lens group of the following conditions (8), (9), (10), and (11).

(8) 0.020<1/(nud)34n < -- 0.033 (9) -0.01<(deltathetagd) 34 -- n < 0.01 (10) 0 -- < -- 1/(nud) 34 -- p < 0.0166 (11) 0.02<(deltathetagd) 34p, however deltathetagd -- the Abbe number of d line of ** material -- nud ** -- it carrying out and the partial dispersion ratio to g line and d line thetagd-nud when referred to as thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) 34p and 34 (deltathetagd)n The average of deltathetagd of the ** material used for the positive lens and negative lens which constitute the 3rd lens group and the 4th lens group, (nud) 34p and 34 (nud)n nud of the ** material used for the positive lens and negative lens which constitute the 3rd lens group and the 4th lens group, respectively It is the average.

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## DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the zoom lens which has the optimal high optical-character ability for the electronic camera using the image sensor with many pixels suitable for the application which captures the electronic camera which

used the camera tube, a solid state image sensor, etc., especially a highly minute image in recent years.

[0002]

[Description of the Prior Art] Generally, in order that an electronic camera may change an optical image into an electronic signal using the small camera tube and the small solid state image sensor of image pick-up area, a lens system bright as an image pick-up lens used for this is needed. Moreover, it will be necessary to arrange optical elements, such as optical members, such as a low pass filter and an infrared cut filter, and the so-called color-separation prism which leads the flux of light to each image sensor like the so-called multi-plate type electronic camera which receives each image of RGB three primary colors with each image sensor, between a lens system and an image sensor, and a big back focus is needed for it as compared with a focal distance.

[0003] Furthermore, in these cameras, there are many applications which photo a dynamic image and it is common to use the zoom lens of the rate of high variable power as a taking lens.

[0004] As a lens system with which are satisfied of these demands, it has forward refractive power sequentially from a body side. The 1st lens group of immobilization in the case of zooming, The 2nd lens group which has the negative refractive power which moves in accordance with an optical axis on the occasion of zooming, and has a fluctuation operation, and the 3rd lens group which has the operation which moves forward and backward on the occasion of zooming, amends fluctuation of the image surface in the case of variable power, and is kept constant, 4 group zoom lens which consists of the 4th lens group with the forward refractive power which has the image formation operation by immobilization on the occasion of zooming is known.

[0005] As an object for camcorders, sequentially from a body side, it has forward refractive power and zooming is faced in recent years. Moreover, the 1st lens group of immobilization, The 2nd lens group with the negative refractive power which moves in accordance with an optical axis on the occasion of zooming, and has a variable power operation, 4 group zoom lens which consists of the 4th lens group with the forward refractive power which has the 3rd lens group of immobilization, the operation which moves forward and backward on the occasion of zooming, amends fluctuation of the image surface in the case of variable power, and is kept constant, and an image formation operation on the occasion of zooming, Sequentially from a body side, it has forward refractive power. The 1st lens group of immobilization in the case of zooming, The 2nd lens group with the negative refractive power which moves in accordance with an optical axis in the case of zooming, and has a variable power operation, 4 group zoom lens which consists of the 3rd lens group with the forward refractive power which has the operation which moves forward and backward on the occasion of zooming, amends fluctuation of the image surface in the case of variable power, and is kept constant, and the 4th lens group with the forward refractive power which has an

image formation operation by immobilization on the occasion of zooming is known.
[0006] It became possible for very many solid state image sensors of the number of pixels to be developed by development of a manufacturing technology in recent years compared with the magnitude of the image pick-up range, for example, to obtain a high definition image like a Hi-Vision image especially. Therefore, the zoom lens which has the very high optical-character ability to which an image pick-up lens can also fully pull out the engine performance of this image sensor has been needed. Moreover, high resolution is needed and the demand of the optical-character ability to an image pick-up lens system is becoming still higher, so that a solid state image sensor becomes small, for example, the magnitude of each pixel of a solid state image sensor becomes small.
[0007] As a zoom lens with which are satisfied of such a demand, the conventional example indicated by each official report of JP,62-153913,A, JP,1-126614,A, JP,6-56453,A, and JP,6-175022,A is known.
[0008]
[Problem(s) to be Solved by the Invention] Although it was generally possible to make it the yield of the aberration in each refracting interface decrease by many carrying out count refraction of the beam of light, and carrying out image formation as little by little as possible in order to obtain high optical-character ability, there was a fault to which the lens of many number of sheets is inevitably needed in this case, consequently a lens system becomes large-sized.
[0009] Moreover, in the case of a zoom lens, since there are many movable groups, the aberration fluctuation accompanying zooming arises. Therefore, ideally, in each lens group, if aberration is amended good, the aberration fluctuation in the case of zooming will not be produced, but it applies to a tele edge from a wide angle edge, and since how to pass along the beam of light in a lens system is not necessarily fixed, some aberration remains. In a zoom lens, if it is going to attain high optical-character ability, the aberration fluctuation by this residual aberration cannot be disregarded. Therefore, in a zoom lens, the lens number of sheets to constitute is increased, it applies to a tele edge from a wide angle edge, and complicated migration is carried out for a lens group, and since aberration fluctuation is amended, it enlarges.
[0010] The demand which miniaturizes a photography camera and a lens system from the need of the camera which captures highly minute images, such as Hi-Vision, in recent years becoming common on the other hand, and it coming to be used in many fields, and using under various conditions is strong. Therefore, by the smallest possible lens number of sheets, it is an easy group configuration and must be made moreover more high optical-character ability. However, if lens number of sheets is lessened, although the means of adopting an aspheric lens can amend monochromatic aberration, such as spherical aberration, it is very difficult monochromatic aberration to amend chromatic aberration good with the combination of the lens of small number of sheets.

[0011] The zoom lens indicated by JP,62-153913,B, JP,1-126614,A, JP,6-56453,A, etc. among the above-mentioned conventional zoom lenses is the lens system which attained high optical-character ability, in order to capture a high definition image, but its portable type type is also complicated while the lens system indicated by JP,1-126614,A, for example consists of five lens groups containing two compensators and is a complicated configuration with many lens groups. Moreover, although the lens systems indicated by JP,6-175022,A are 4 group configurations, axial overtone aberration cannot say that it is still amended fully.
[0012] It is in offering the small zoom lens which amended the high optical-character ability this invention is a comparatively easy configuration, and there is little lens number of sheets, and optimal for the electronic camera using the camera tube, a solid state image sensor, etc., especially the electronic camera using the image sensor with many pixels suitable for the application which captures a highly minute image in recent years, especially chromatic aberration good.
[0013]
[Means for Solving the Problem] The 1st lens group in which the zoom lens of this invention has forward refractive power sequentially from a body side, The 2nd lens group which moves in accordance with an optical axis on the occasion of zooming with negative refractive power, and carries out a variable power operation, It consists of the 3rd lens group with forward refractive power, and the 4th lens group of forward refractive power. It is characterized by being satisfied with the lens system which amended fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses in said 3rd lens group, said 4th lens group, or these lens group of the following conditions (1), (2), and (3).
[0014]
(1) 0.25 -- < -- 1/(nud) 1 -- n< 0.04 (2) -0.005<(deltathetagd) 1 -- n< 0.02 (3) 0 -- < -- 1/(nud)1p<0.0166, however deltathetagd -- the Abbe number of d line of ** material -- nud ** -- it carrying out and the partial dispersion ratio to g line and d line thetagd-nud when referred to as thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) The average of deltathetagd of the ** material used for the negative lens which constitutes the 1n of the 1st lens groups, and 1 (nud)p and 1 (nud)n are nud of the ** material used for the positive lens and negative lens which constitute the 1st lens group, respectively. It is the average.
[0015] Drawing 25 is thetagd-nud. It is a graph and Line A is a line which connects K7 and F2 on this graph. Although not shown in this drawing, many of ordinary glass is mostly distributed according to this line as everyone knows.
[0016] deltathetagd is thetagd-nud as mentioned above here. The amount of gaps of the vertical direction (the direction of an axis of ordinate) from a line to which the point on the graph of K7 (nd =1.51112, nud =60.5) and F2 (nd =1.62004, nud =36.3) was connected in the graph is expressed. That is, the upper part or the line which carried out the parallel displacement only of the value of deltathetagd caudad is

shown for the line A which connected the point K7 shown in drawing 25 , and the point F2. Therefore, for deltathetagd=0.04 of the upper limit of conditions (2), deltathetagd=0.025 of a line A1 and a minimum are a line A2. It hits. Moreover, conditions (1) will be set to 40>(nud)1n >25 if it is made into the inverse number, and a line B1 and a minimum are [ an upper limit ] line B-2 on a graph on a graph. It becomes. Therefore, when conditions (1) and (2) are doubled, they are a line A1, A2, B1, and B-2. The surrounded shadow area is within the limits of conditions (1) and conditions (2). That is, by this invention, if the negative lens in the 1st lens group averages, it means being contained within the limits of said strabism.

[0017] Moreover, there are the following as a lens system of the configuration of the 2nd of the zoom lens of this invention. In accordance with an optical axis, it moves with the 1st lens group with forward refractive power sequentially from a body side with negative refractive power in the case of zooming. A variable power operation Namely, the 2nd lens group, It consists of the 3rd lens group with forward refractive power, and the 4th lens group with forward refractive power. It is the lens system which amends fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses of said 3rd lens group, said 4th lens group, or these lens group, and is the zoom lens with which are satisfied of the following conditions (4), (5), (6), and (7).

[0018]

(4) 0.014<1/(nud)2n<0.017 (5) -0.01<(deltathetagd)2n<0.01 (6) 0.030<1/(nud)2p (7) 0.015<(deltathetagd) 2p, however deltathetagd the Abbe number of d line of ** material nud thetagd-nud when carrying out and setting the partial dispersion ratio to g line and d line to thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) The average of deltathetagd of the ** material used for the positive lens and negative lens which constitute the 2nd lens group 2p and 2 (deltathetagd)n, respectively, and 2 (nud)p and 2 (nud)n are nud of the ** material used for the positive lens and negative lens which constitute the 2nd lens group, respectively. It is the average.

[0019] Furthermore, there are some which are described below as a lens system of the configuration of the 3rd of the zoom lens of this invention. Namely, the 1st lens group which has forward refractive power sequentially from a body side and the 2nd lens group which moves in accordance with an optical axis on the occasion of zooming with negative refractive power, and carries out a variable power operation, It consists of the 3rd lens group with forward refractive power, and the 4th lens group with forward refractive power. The zoom lens which is satisfied with the lens system which amends fluctuation of the image surface location at the time of the variable power by migration of said 2nd lens group using some lenses of said 3rd lens group, said 4th lens group, or these lens group of the following conditions (8), (9), (10), and (11).

[0020]

(8) 0.020<1/(nud)34n < -- 0.033 (9) -0.01<(deltathetagd) 34 -- n < 0.01 (10) 0 -- < -- 1/(nud) 34 -- p < 0.0166 (11) 0.02<(deltathetagd) 34p, however deltathetagd -- the Abbe number of d line of ** material -- nud ** -- it carrying out and the partial dispersion ratio to g line and d line thetagd-nud when referred to as thetagd The difference of **** from the straight line which connects K7 and F2 on a graph, (deltathetagd) 34p and 34 (deltathetagd)n The average of deltathetagd of the ** material used for the positive lens and negative lens which constitute the 3rd lens group and the 4th lens group, (nud) 34p and 34 (nud)n nud of the ** material used for the positive lens and negative lens which constitute the 3rd lens group and the 4th lens group, respectively It is the average.

[0021] In order to attain a zoom lens with the small zoom lens for camcorders etc. Sequentially from a body side, it has forward refractive power and zooming is faced. As mentioned above, the 1st lens group of immobilization, The 2nd lens group with the negative refractive power which moves in accordance with an optical axis on the occasion of zooming, and has a variable power operation, 4 group zoom lens which consists of the 4th lens group with the forward refractive power which has the 3rd lens group of immobilization, the operation which moves forward and backward in the case of zooming, amends fluctuation of the image surface by variable power, and is kept constant, and an image formation operation on the occasion of zooming, Sequentially from a body side, it has forward refractive power. In the case of zooming The 1st lens group of immobilization, The 2nd lens group with the negative refractive power which moves in accordance with an optical axis in the case of zooming, and has a fluctuation operation, There is a 4 group zoom lens which consists of the 3rd lens group which has the operation which moves forward and backward on the occasion of zooming, amends fluctuation of the image surface in the case of variable power, and is kept constant, and has forward refractive power, and the 4th lens group which is immobilization in the case of zooming, has an image formation operation and has forward refractive power.

[0022] Although the zoom lens of these former is an easy configuration and it is a zoom type suitable for the miniaturization which secured efficiently the tooth space from which a movable group is moreover moved, since the configuration number of sheets of each lens group is lessened in order to attain a miniaturization, and refractive power is strengthened, there is a fault from which aberration fluctuation becomes size.

[0023] Therefore, the conventional example which was made to perform aberration amendment using the aspheric lens is increasing. However, there is no capacity for an aspheric lens to amend chromatic aberration although there is effectiveness in amendment of the monochromatic aberration, and the optical-character ability demanded as an image formation lens which captures a highly minute image cannot be attained only by using an aspheric lens. In order to amend chromatic aberration sufficiently good in a lens system with little above configuration number of sheets, it

is necessary to choose the ** material to be used enough in consideration of an optical property.
[0024] The wavelength from which a film-based camera, an electronic camera, etc. are especially set as the amendment object of chromatic aberration reaches far and wide, the so-called amendment of a secondary spectrum must become very important, and the optical property of the ** material to be used must also fully take into consideration a refractive index and not only the Abbe number but an anomalous-scattering property. Amendment of the primary chromatic aberration which furthermore amends the chromatic aberration of C line and an F line, and a secondary spectrum, and amendment of chromatic aberration and amendment of the monochromatic aberration are difficult to be contradictory in many cases and to amend both good.
[0025] This invention examines the optical property of the ** material used as a lens ingredient, and amends the monochromatic aberration, the primary chromatic aberration, a secondary spectrum, etc. good.
[0026] In the zoom lens of this invention, the 1st lens group is applied to a tele edge from a wide angle edge, and since the behavior of the beam of light which passes a lens system is changed sharply, many aberration must be especially amended enough by the 1st lens group independent. Since the 1st lens group has forward refractive power when it thinks from a viewpoint which amends chromatic aberration, it is necessary to use the ** material of low distribution for a negative lens for the ** material of high distribution at a positive lens. However, amendment of the chromatic aberration by the combination of such ** material is amendment which makes equal chromatic aberration generated in the primary achromatism, i.e., C line and an F line, and is not effective in amendment of a secondary spectrum, and ** material is limited further.
[0027] Like the zoom lens of this invention, in order that the secondary spectrum in short wavelength regions, such as g line, may usually pose a problem and taking lenses, such as a film-based camera and an electronic camera, may amend the primary chromatic aberration, the chromatic aberration over g line is greatly generated in the forward direction. Therefore, in order to amend a secondary spectrum, it is necessary to return the chromatic aberration over g line to a negative direction. For that purpose, what is necessary is to make high relatively the refractive index to g line of a positive lens, or just to make low relatively the refractive index to g line of a negative lens.
[0028] What is necessary is here, just to make the value of deltathetagd into smallness, in order to make the value of deltathetagd into size in order to make the refractive index of g line high relatively, and considering deltathetagd which shows the anomalous-scattering nature in the short wavelength region of ** material to make the refractive index of g line low relatively again. That is, a positive lens makes the value of deltathetagd size and a negative lens should just make the value of

deltathetagd smallness. This condition is not acquired with the relation between behavior of the chromatic aberration of the whole lens system, and the refractive index to g line, and is not related to the positive/negative of a lens group.
[0029] Next, if a glass map is examined, the value of deltathetagd of the high-dispersion glass material with the small Abbe number is size, and deltathetagd will decrease as the Abbe number becomes large. And if it classifies roughly, about, deltathetagd becomes a value near 0 about nud =35, and two kinds, the so-called Normal glass with the small value of |deltathetagd| and the lanthanum system glass in which deltathetagd has a negative big value, are distributed before about nud =60. Although Normal glass exists up to the d = nu70 neighborhood about, if it becomes an about big value from the d = nu63 neighborhood, the so-called anomalous dispersion glass with the big value of deltathetagd comes to be distributed.
[0030] In the lens system of this invention, although it is desirable for the primary color correction to use high-dispersion glass material as for the negative lens in the 1st lens group, since deltathetagd becomes size too much, high-dispersion glass material is unsuitable to amendment of a secondary spectrum. As ** material used for the positive lens of a **** 1 lens group, although the so-called anomalous dispersion glass with the large value of deltathetagd is suitable by low distribution, since a refractive index becomes low, amendment of other monochromatic aberration becomes difficult.
[0031] The above point is considered and it was made for the zoom lens of this invention to satisfy the aforementioned conditions (1), (2), and (3) for the 1st lens group.
[0032] Although distribution of a negative lens becomes large and is desirable for the primary color correction when the upper limit of conditions (1) is exceeded, it becomes difficult to choose the ** material which satisfies the conditions (2) which are conditions for amending a secondary spectrum. Moreover, if the minimum of conditions (1) is exceeded, distribution of a negative lens will become smallness, the primary color correction becomes difficult, and the chromatic aberration of the scale factor especially in a wide angle edge will remain greatly.
[0033] If the upper limit of conditions (2) is exceeded, the anomalous-scattering nature of a negative lens will move to hard flow, and especially, amendment of the axial overtone aberration in a tele edge becomes difficult, and if a minimum is exceeded, the ** material which satisfies conditions (1) will no longer be obtained.
[0034] If the upper limit of conditions (3) is exceeded, as ** material used for a positive lens, distribution will become large too much, and amendment of the chromatic aberration of the scale factor in a wide angle edge will become difficult.
[0035] In the above-mentioned zoom lens, in order to make amendment of a secondary spectrum much more good, it is desirable to satisfy the following conditions (12).
[0036] (12) 0.02<(deltathetagd) 1p -- 1(deltathetagd) p is the average of deltathetagp

of the positive lens of the 1st lens group here.
[0037] If the minimum of this condition (12) is exceeded, the amendment effectiveness of the secondary spectrum in a positive lens will not fully be acquired, but advanced color correction will become difficult.
[0038] In order to make an amendment operation of the secondary spectrum by the positive lens of the 1st lens group increase further, it is desirable to satisfy the following conditions (12').
(12') 0.03<(deltathetagd) 1p [0039] In a wide angle edge, the 1st lens group of the zoom lens of this invention needs to bend smoothly the high axial ray of beam-of-light quantity in a tele edge, and needs to lead the axial outdoor daylight line of a large field angle to the 2nd lens group again. Therefore, as for this 1st lens group, it is more desirable than a body side to constitute from a negative meniscus lens which turned the convex to the body side, and at least two positive lenses in order, and to make the positive lens by the side of an image into the forward meniscus lens which turned the convex to the body side further.
[0040] Furthermore, as for the positive lens by the side of a body, it is desirable between at least two positive lenses of the aforementioned 1st lens group to strengthen refractive power in a meniscus configuration or both the convex configuration. or [ that it is the same as the refractive index of the positive lens by the side of an image in the refractive index of the positive lens by the side of a body in order to amend the monochromatic aberration, especially the PETTSU bar sum good here ] -- or it is desirable to make it high.
[0041] Next, in the zoom lens of this invention, since the 2nd lens group is a lens group of negative refractive power and it is the lens group which mainly takes charge of variable power, the refractive power is in size, and since it moreover moves greatly on the occasion of zooming, aberration fluctuation becomes a problem. So, in order [ in the 2nd lens group ] to suppress especially generating of the monochromatic aberration, it is desirable to increase the number of sheets of a negative lens and to distribute negative refractive power. However, considering chromatic aberration, generating of the chromatic aberration of the negative scale factor in a wide angle edge is size, and the amendment especially becomes very difficult. Therefore, as for the 2nd lens group, it is desirable to constitute in order from a negative lens which turned the field of the strong one of negative refractive power to the image side, a negative lens, and a positive lens which turned the field of the strong one with forward refractive power to the body side, and to choose the ** material to be used from a body side as it appropriately.
[0042] Since this 2nd lens group has negative refractive power, it becomes the primary achromatic condition about the ** material of low distribution to arrange the ** material of high distribution at a positive lens, a configuration, i.e., a negative lens, contrary to the 1st lens group. However, for amendment of a secondary spectrum, it is desirable to make deltathetagd at a positive lens and to make deltathetagd small

greatly like the 1st lens group, again at a negative lens.

[0043] As a result of examining suitable ** material in consideration of these points, satisfying conditions (4) shown above, (5), (6), and (7) found out the desirable thing.

[0044] If the upper limit of conditions (4) is exceeded, distribution of a negative lens will become size too much, the primary color correction will become difficult, and it becomes difficult to amend the chromatic aberration of a scale factor in a wide angle edge and the axial overtone aberration in a tele edge to coincidence. Moreover, if a minimum is exceeded, negative distribution will become small too much and selection of the ** material which satisfies the conditions for amendment of the secondary spectrum in this lens group (5) will become difficult.

[0045] If the upper limit of conditions (5) is exceeded, while the amendment effectiveness of a secondary spectrum will decrease, the ** material which can be used is limited to the ** material of a low refractive index or high distribution. In the case of the former ** material of low distribution, the negative PETTSU bar sum generated with a negative lens becomes size too much, it becomes impossible to amend a curvature of field, and, in the case of the latter ** material of high distribution, the primary color correction becomes difficult. Moreover, if the minimum of conditions (5) is exceeded, it will be limited to the ** material of a lanthanum system with a high refractive index, distribution will become large, and the primary color correction will become inadequate.

[0046] If the minimum of conditions (6) is exceeded, distribution of a positive lens will become small, the primary color correction is inadequate and it becomes difficult to amend the chromatic aberration of a scale factor in a wide angle edge and the axial overtone aberration in a tele edge to coincidence.

[0047] If the minimum of conditions (7) is exceeded, selection of the ** material which satisfies conditions (6) will become difficult.

[0048] In order to heighten the amendment effectiveness of the secondary spectrum by the positive lens in the 2nd lens group, it is desirable to satisfy conditions (7'), and to satisfy conditions (7″), in order to raise further.

(7') 0.020<(deltathetagd) 2p (7″) 0.025<(deltathetagd) 2p [0049] Furthermore, in the zoom lens of this invention, it is the lens group to which image formation of the emission flux of light which injected the 2nd lens group is carried out, some lenses of the 3rd lens group, the 4th lens group, or these 3rd and 4th lens group have the role of a compensator, and the 3rd lens group and the 4th lens group move an optical-axis top forward and backward on the occasion of zooming. However, since these migration length is smallness comparatively, the generating situation of the aberration applied to a tele edge from a wide angle edge is comparatively stable.

[0050] Although what is necessary is just to perform aberration amendment in the same idea as the 1st lens group since each of these 3rd lens groups and 4th lens groups is positive lens groups, since it is an image formation lens group, the 3rd and 4th lens group must take into consideration the effect forward refractive power

affects the aberration, especially the PETTSU bar sums other than chromatic aberration strongly. As a result of examining ** material about the 3rd and 4th lens group in consideration of this point, satisfying conditions (8) shown above, (9), (10), and (11) found out the desirable thing.
[0051] Although distribution of a negative lens becomes large and is advantageous to the primary color correction if the upper limit of conditions (8) is exceeded, it becomes difficult to choose the ** material of deltathetagd which satisfies conditions (9). Moreover, if the minimum of conditions (8) is exceeded, distribution of a negative lens will become small, the primary color correction becomes difficult, and it becomes difficult to amend the chromatic aberration of a scale factor in a wide angle edge and the axial overtone aberration in a tele edge to coincidence.
[0052] If the upper limit of conditions (9) is exceeded, it will become the direction which amends a secondary spectrum to hard flow, and if a minimum is exceeded, it will become difficult to obtain the ** material which satisfies conditions (8).
[0053] If the upper limit of conditions (10) is exceeded, it is difficult for distribution of a positive lens to become large too much, and for the primary color correction to become difficult, and to amend the chromatic aberration of a scale factor in a wide angle edge, and the axial overtone aberration in a tele edge to coincidence.
[0054] If the minimum of conditions (11) is exceeded, the amendment effectiveness of a secondary spectrum will become small and the desired chromatic-aberration engine performance will not be obtained.
[0055] The low-dispersion glass material with which are satisfied of the above-mentioned conditions (10) and (11) has a possibility that a refractive index may be small and a PETTSU bar may get worse. In order to prevent this, it is desirable to constitute from a 41st lens group which has forward refractive power for the 4th lens group in order [ side / body ], and a 42nd lens group which has negative refractive power. Even if it increases the negative refractive power of the 2nd lens component and amends the PETTSU bar sum by making the 4th lens group such a configuration, the axial ray quantity which passes this 2nd lens component can make min effect of the low aberration on others. Moreover, in order to amend the PETTSU bar sum good, it is desirable for making the refractive index of a positive lens as high as possible to specifically satisfy the following conditions (13) desirably.
[0056]
(13) 1.48<(ne)34p <1.65, however 34(ne) p It is the average of the refractive index in e line of the positive lens which constitutes the 3rd lens group and the 4th lens group.
[0057] If it becomes impossible to choose the ** material which will satisfy conditions (11) if the upper limit of conditions (13) is exceeded and a minimum is exceeded, even if aggravation of the PETTSU bar sum will be remarkable and will enlarge refractive power of a negative lens, it cannot amend without causing aggravation of other aberration.
[0058] Moreover, when the need of using the ** material of high distribution for the

negative lens used for the 1st lens group for amendment of the chromatic aberration of a scale factor is high, it is desirable to heighten the amendment effectiveness of the secondary spectrum in the 3rd lens group and the 4th lens group. Specifically, it is desirable to satisfy the following conditions (9') and (11').

[0059] (9') $-0.005<(deltathetagd)34n <0.005$ (11') In a $0.025<(deltathetagd)34p$ this invention lens system, in order to amend aberration good further, it is desirable to satisfy the following conditions (14), (15), (16), (17), (18), and (19).

[0060]

(14) $0.10<phi1 / phiW <0.21$ (15) $0.54<|phi2 /phiW |<0.76$ (16) $0.10<phi3/phiW <0.26$ (17) $0.26<phi4/phiW <0.45$ (18) $0.19<|phi42/phiW |<0.48$ (19) It corrects $0.38<|phi42-/phi41|<0.74$. The refractive power of the 1st lens component of phi 1, phi 2, phi 3, phi 4, phi41 and phi42, the 1st lens group of ******, the 2nd lens group, the 3rd lens group, the 4th lens group, and the 4th lens group, and the 2nd lens component of the 4th lens group, and phiW It is the refractive power of the whole system in a wide angle edge.

[0061] Although it is advantageous in order for it to become impossible to maintain balance and to shorten reservation and overall length of the back focus of a lens system, if the refractive power of the 1st lens group becomes size exceeding the upper limit of conditions (14) and refractive power of the 2nd lens group will not be made into size, either, many aberration especially the spherical aberration in a tele edge, comatic aberration, and astigmatism get worse, and it cannot amend by other lens groups. Moreover, if the refractive power of the 1st lens group becomes smallness exceeding the minimum of conditions (14), amendment of the axial overtone aberration generated by the 3rd lens group or the 4th lens group, the chromatic aberration of a scale factor, and spherical aberration will especially become difficult, and the residual aberration applied to a middle focal distance from a wide angle edge will become large.

[0062] Although it is advantageous in order to shorten reservation and overall length of the back focus of a lens system if the refractive power of the 2nd lens group becomes size exceeding the upper limit of conditions (15), fluctuation of the chromatic aberration of a scale factor is large at the time of fluctuation of many aberration which it is necessary to increase the refractive power of the lens group of either of the positive lens groups, therefore is applied to a tele edge from a wide angle edge. Moreover, if the refractive power of the 2nd lens group becomes smallness exceeding the minimum of conditions (15), in order to secure a variable power ratio, migration length of the 2nd lens group must be made into size, and a lens system becomes large-sized. Furthermore, it becomes difficult to amend the negative spherical aberration generated by the positive lens group good, and fluctuation of spherical aberration becomes size.

[0063] When the refractive power of the 3rd lens group becomes size exceeding the upper limit of conditions (16), or the minimum of conditions (17) is exceeded and the

refractive power of the 4th lens group becomes smallness, forward refractive power in the 3rd lens group An assembly, Especially, the rate of generating of axial overtone aberration and the chromatic aberration of a scale factor changes, from a wide angle edge, it becomes difficult to apply to a tele edge and to amend with sufficient balance, and axial overtone aberration remains greatly in the chromatic aberration or the tele edge of a scale factor in a wide angle edge. When priority is given to amendment of chromatic aberration here, especially fluctuation of a meridional image surface becomes large, and amendment becomes difficult. Moreover, if the refractive power of the 4th lens group becomes size exceeding the upper limit of the article affair (17) in which the refractive power of the 3rd lens group becomes smallness exceeding the minimum of conditions (16), the spherical aberration and the axial overtone aberration which forward refractive power generates by the assembly and the 4th lens group in the 4th lens group will increase, and amendment will become difficult.

[0064] If the value of |phi42-/phi41| becomes size exceeding the upper limit of the article affair (19) in which the value of |phi42-/phiW| becomes size exceeding the upper limit of conditions (18) The comatic aberration applied to a middle focal distance from the chromatic aberration in a wide angle edge, the meridional curvature of field in a tele edge, and a wide angle edge by it becoming difficult for the amendment contribution to the axial ray in the 4th lens group and the amendment contribution to an axial outdoor daylight line to change, and to maintain balance remains greatly and is not desirable. Conversely, if the value of |phi42-/phi41| becomes small exceeding the minimum of the article affair (19) in which the value of |phi42-/phiW| becomes small exceeding the minimum of conditions (18), fluctuation of the meridional curvature of field applied to a tele edge from a wide angle edge and axial overtone aberration will become large. Furthermore, it becomes difficult for the spherical aberration applied to a tele edge to remain greatly, and to amend from a middle focal distance.

[0065] furthermore, conditions (14) thru/or conditions (19) -- setting -- the value of the bound -- the following conditions (14') -- or (19') if it is made to be shown, it is much more desirable.

[0066]

(14') 0.12<phi1 / phiW <0.17 (15') 0.57<|phi2 /phiW |<0.73 (16') 0.10<phi3 /phiW <0.23 (17') 0.30<phi4/phiW <0.41 (18') 0.22<|phi42/phiW |<0.45 (19') 0.41<|phi42/phi41|<0.70 and also conditions (14), It is desirable to satisfy the following conditions (14''), (16''), and (19'') instead of (16) and (19).

(14'') 0.125<phi1/phiW<0.145 (16'') 0.17<phi3/phiW<0.23 (19'') 0.45<|phi42/phi41|<0.70[0067]

[Example] Next, each example of the zoom lens of this invention is shown.

Example 1f=9.061 -25.464-71.998 F/2.0 2omega=49.947 degree-18.297 degree-6.327 **r1 =139.5134 d1 =2.5000 n1 =1.81264 nu1 =25.43 deltathetagd=0.0165r2 =80.9589 d2 =1.0000r3 =103.9774 d3 =7.2273 n2 =1.43985 nu2 =94.97 deltathetagd=0.0622r4 =-

249.3944 d4 =0.1500r5 =48.1566 d5 =6.3422 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r6 =390.6397 d6 =0.1500r7 =36.0540 d7 =4.2911 n4=1.43985 nu4 =94.97 deltathetagd=0.0622r8 =61.0815 d8 =D1 (adjustable)
r9 =61.5748 d9 =1.5000 n5 =1.60548 nu5 =60.70 deltathetagd=-0.0032 r10=15.7087 d10=14.9271 r11=-21.1656 d11=1.5000 n6 =1.60548 nu6 =60.70 deltathetagd=-0.0032 r12=20.7844 d12=0.1500r13=20.6360 d13=8.6002 n7 =1.84281 nu7 =21.00 deltathetagd=0.0356r14=57.3063 d14=D2 (adjustable)
r15=infinity (diaphragm)
d15=1.0000r16=-331.3956 d16=2.5000 n8 =1.57098 nu8 =71.30 deltathetagd=0.0266r17=-32.3660 d17=0.1500r18=15.8324 d18=2.5000 n9 =1.57098 nu9 =71.30 deltathetagd=0.0266r19=-158.1052 d19=0.8531r20=-26.1704 d20=1.5000 n10=1.80642 nu10=34.97 deltathetagd=0.0003r21=80.3910 d21=D3 (adjustable)
r22=70.0995 d22=2.8000 n11=1.57098 nu11=71.30 deltathetagd=0.0266r23=-20.7695 d23=0.1500r24=19.7179 d24=8.7237 n12=1.57098 nu12=71.30 deltathetagd=0.0266r25=-105.4606 d25=0.7647r26=-18.6567 d26=1.5000 n13=1.85649 nu13=32.28 deltathetagd=0.0022r27=-174.0609 f 9.06125.464 71.998D1 1.400019.7747 33.1226 D2 34.678716.2987 2.9565D3 7.3055 4.8140 8.09611/(nud)1n=0.039, 1/() [ nud ] 1p=0.011 and 1(deltathetagd) n=0.017 (deltathetagd) 1p=0.062, 1/() [ nud ] 2n=0.017 and 1/(nud)2p=0.048 (deltathetagd) 2n=-0.003, 2(deltathetagd) p=0.036, 1/(nud)34n =0.030 1/(nud)34p =0.014, and 34(deltathetagd) n =0.001 (deltathetagd) 34p =0.027 (), [ ne ] 34p =1.571, phi1/phiW =0.136|phi2/phiW |=0.691, phi3/phiW =0.182, phi4/phiW =0.392 |phi42/phiW |=0.370, and |phi42/phi41|=0.609 [0068] Example 2f=9.046 -25.465-71.992 F/2.0 2omega=50.417 degree-18.243 degree-6.344 **r1 =152.3247 d1 =2.5000 n1 =1.81264 nu1 =25.43 deltathetagd=0.0165r2 =83.1327 d2 =1.0000r3 =103.0268 d3 =5.5936 n2 =1.43985 nu2 =94.97 deltathetagd=0.0622r4 =-236.3738 d4 =0.1500r5 =48.2477 d5 =5.9198 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r6 =440.1637 d6 =0.1500r7 =34.9932 d7 =4.0660 n4=1.43985 nu4 =94.97 deltathetagd=0.0622r8 =61.8422 d8 =D1 (adjustable)
r9 =72.3857 d9 =1.5000 n5 =1.60548 nu5 =60.70 deltathetagd=-0.0032 r10=14.5704 d10=12.4293 r11=-19.9601 d11=1.5000 n6 =1.60548 nu6 =60.70 deltathetagd=-0.0032 r12=21.1642 d12=0.1500r13=21.0503 d13=6.1625 n7 =1.84281 nu7 =21.00 deltathetagd=0.0356r14=69.8615 d14=D2 (adjustable)
r15=infinity (diaphragm)
d15=1.0000r16=-287.7720 d16=2.5000 n8 =1.57098 nu8 =71.30 deltathetagd=0.0266r17=-30.3056 d17=0.1500r18=16.9576 d18=2.5000 n9 =1.57098 nu9 =71.30 deltathetagd=0.0266r19=-87.5745 d19=2.0057r20=-25.8774 d20=1.2000 n10=1.80642 nu10=34.97 deltathetagd=0.0003r21=66.8633 r22=61.9059d22=2.8000 n11=1.57098 nu11=71.30 deltathetagd=0.0266r23=-21.0746 d23=0.1500r24=21.0941 d24=7.3060 n12=1.57098 nu12=71.30 deltathetagd=0.0266r25=-79.5816 d25=0.7497r26=-21.1787 d26=1.2000 n13=1.85649 nu13=32.28 deltathetagd=0.0022r27=-356.0244 d27=1.0000r28=infinity d28=7.0000 n14=1.51825

nu14=64.15 r29=infinityf 9.046 25.465 71.992D1 1.4000 19.8294 33.1916 D2 34.3586 15.9299 2.5658D3 8.2701 5.1604 7.91181/(nud)1n=0.039, 1/() [ nud ] 1p=0.011 and 1(deltathetagd) n=0.017 (deltathetagd) 1p=0.062, 1/() [ nud ] 2n=0.017 and 1/(nud)2p=0.048 (deltathetagd) 2n=-0.003, 2(deltathetagd) p=0.036, 1/(nud)34n =0.030 1/(nud)34p =0.014, 34(deltathetagd) n =0.001 34(deltathetagd) p =0.027 (), [ ne ] 34p =1.571, phi1/phiW =0.140|phi2/phiW |=0.707, phi3/phiW =0.199, phi4/phiW =0.389 |phi42/phiW |=0.344, and |phi42/phi41|=0.564 [0069] Example 3f=9.150 -25.430-71.943 F/2.0 2omega=50.125 degree-17.851 degree-6.284 **r1 =67.3534 d1 =1.8000 n1 =1.80642 nu1 =34.97 deltathetagd=0.0003r2 =41.7227 d2 =5.3000 n2 =1.43985 nu2 =94.97 deltathetagd=0.0622r3 =-310.9797 d3 =0.1000r4 =36.7193 d4 =3.9573 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r5 =204.0192 d5 =D1 (adjustable)
r6 =-176.6655 d6 =1.0000 n4 =1.65425 nu4 =58.52 deltathetagd=-0.0050 r7 =12.9811 d7 =3.7851r8 =-24.9700 d8 =1.0000 n5 =1.65425 nu5 =58.52 deltathetagd=-0.0050 r9 =68.5111 d9 =0.2000r10=28.4668 d10=2.8000 n6 =1.84281 nu6 =21.00 deltathetagd=0.0356r11=190.5820 d11=D2 (adjustable)
r12=infinity (diaphragm)
d12=1.1000r13=15.2088 (aspheric surface)
d13=3.8000 n7 =1.57098 nu7 =71.30 deltathetagd=0.0266r14=-55.0074r15=37.4721 d15=D3 (adjustable)
r16=22.0013 (aspheric surface)
d16=2.8000 n9 =1.57098 nu9 =71.30 deltathetagd=0.0266r17=802.9020 d17=0.1000r18=24.9962 d18=1.0000 n10=1.75453 nu10=35.27 deltathetagd=0.0036r19=17.2865 d19=2.8000 n11=1.57098 nu11=71.30 deltathetagd=0.0266r20=-53.7034 d20=0.1000r21=13.9402 d21=1.3321n12=1.63004 nu12=35.70 deltathetagd=0.0002r22=8.5579 aspheric-surface multiplier (the 13th page) A4 =-0.27966x10-4 A6 =-0.87535x10-7A8 =-0.15668x10-9 A4 (16th page) =-0.54064x10-4 A6 =-0.98203x10-8 A8 =-0.16407x10-9f 9.150 25.43071.943D1 1.5000 22.8193 39.2193 D2 39.7158 18.3971 2.0017D3 7.6660 3.2561 2.83871/(nud) 1 n= 0.029, 1/(nud)1p=0.011, 1(deltathetagd) n=0.000 1(deltathetagd) p=0.062, 1/(nud)2n=0.017, and 1/(nud)2p=0.048 (deltathetagd) 2n=-0.005, 2(deltathetagd) p=0.036, 1/(nud)34n=0.028 1/(nud)34p =0.014, and 34(deltathetagd) n =0.002 34(deltathetagd) p =0.027 (), [ ne ] 34p =1.571, phi1/phiW =0.131 |phi2/phiW|=0.605, phi3/phiW =0.193, phi4/phiW =0.319 |phi42/phiW |=0.235, and |phi42/phi41|=0.484 [0070] Example 4f=8.938 -25.441-71.978 F/2.0 2omega=49.346 degree-17.658 degree-6.204 **r1 =94.8594 d1 =1.8000 n1 =1.85649 nu1 =32.28 deltathetagd=0.0022r2 =52.0731 d2 =5.5535 n2 =1.43985 nu2 =94.97 deltathetagd=0.0622r3 =-330.4893 d3 =0.1000r4 =44.1397 d4 =4.1218 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r5 =175.9434 d5 =0.1000r6 =40.1589 d6 =3.9902n4 =1.43985 nu4 =94.97 deltathetagd=0.0622r7=145.1529 d7 =D1 (adjustable)
r8 =609.3378 d8 =1.0000 n5 =1.62033 nu5 =63.38 deltathetagd=0.0070r9 =10.5608 d9 =4.4739r10=-44.5113 d10=1.0000 n6 =1.62033 nu6 =63.38

deltathetagd=0.0070r11=35.1888 d11=0.1688r12=17.3152 d12=0.9992 n7 =1.84281 nu7 =21.00 deltathetagd=0.0356r13=30.9795 d13=D2 (adjustable)
r14=infinity (diaphragm)
d14=1.1000r15=-17.9714 (aspheric surface)
d15=1.2101 n8 =1.62033 nu8 =63.38 deltathetagd=0.0070r16=-28.9343
d16=0.1000r17=25.1740 d17=1.6914 n9 =1.60520 nu9 =65.48 deltathetagd=0.0059r18=-67.6119 d18=0.8091 n10=1.64419 nu10=34.48 deltathetagd=0.0016r19=-282.2911
d19=D3 (adjustable)
r20=288.5352 (aspheric surface)
d20=3.6317 n11=1.43985 nu11=94.97 deltathetagd=0.0622r21=-21.9444
d21=0.1000r22=16.6233 d22=1.0000 n12=1.69417 nu12=31.08
deltathetagd=0.0024r23=9.4208 d23=5.0129 n13=1.62033 nu13=63.38
deltathetagd=0.0070r24=-76.6563 d24=0.1000r25=18.2512 d25=1.3824 n14=1.63004 nu14=35.70 deltathetagd=0.0002r26=9.9560 aspheric-surface multiplier (the 15th page) A4 =-0.28298x10-4 A6 =-0.90598x10-7A8 =-0.75613x10-9 A4 (20th page) =-0.64725x10-4 A6 =-0.55523x10-7 A8 =-0.13010x10-9f 8.938 25.44171.978D1 1.5000 19.8080 33.9524 D2 33.4539 15.1482 1.0044D3 8.7909 6.7174 13.6922 1/(nud)1n=0.031, 1/(nud)1p=0.011, 1(deltathetagd) n=0.002 1(deltathetagd) p=0.062, 1/(nud)2n=0.016, and 1/(nud)2p=0.048 (deltathetagd) 2n=0.007, 2(deltathetagd) p=0.036, 1/(nud)34n=0.024 1/(nud)34p =0.013, and 34(deltathetagd) n =0.003 34(deltathetagd) p=0.025 (), [ ne ] 34p =1.555, phi1/phiW =0.157|phi2/phiW |=0.629, phi3/phiW =0.124, phi4/phiW =0.395 |phi42/phiW |=0.241, and |phi42/phi41|=0.435 [0071] Example 5f=9.304 -25.457-71.964 F/2.0 2omega=49.471 degree-17.846 degree-6.262 **r1 =69.3098 d1 =1.8000 n1 =1.85649 nu1 =32.28 deltathetagd=0.0022r2 =43.4214 d2 =5.1245 n2 =1.49845 nu2 =81.61 deltathetagd=0.0364r3 =-460.3535 d3 =0.1000r4 =37.6226 d4 =4.0485 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r5 =185.5159 d5 =D1 (adjustable)
r6 =-251.4932 d6 =1.0000 n4 =1.60548 nu4 =60.70 deltathetagd=-0.0032 r7 =12.5818 d7 =4.6702r8 =-23.2644 d8 =1.0000 n5 =1.60548 nu5 =60.70 deltathetagd=-0.0032 r9 =75.0852 d9 =0.1433r10=28.1893 d10=2.0000 n6 =1.84281 nu6 =21.00
deltathetagd=0.0356r11=114.7892 d11=D2 (adjustable)
r12=infinity (diaphragm)
d12=1.1000r13=16.8270 (aspheric surface)
d13=3.0702 n7 =1.57098 nu7 =71.30 deltathetagd=0.0266r14=-45.9010 (aspheric surface)
d14=0.8305r15=-29.2714 d15=0.8000 n8 =1.64419 nu8 =34.48
deltathetagd=0.0016r16=163.1174 d16=D3 (adjustable)
r17=38.0917 (aspheric surface)
d17=2.0000 n9 =1.57098 nu9 =71.30 deltathetagd=0.0266r18=-35.1200
d18=0.1000r19=16.2153 d19=1.0000 n10=1.80642 nu10=34.97
deltathetagd=0.0003r20=10.0172 d20=4.2918 n11=1.57098 nu11=71.30

deltathetagd=0.0266r21=-51.0748 d21=0.1000r22=66.1152 d22=1.3243n12=1.60548 nu12=60.70 deltathetagd=-0.0032 r23=10.9915 Aspheric surface multiplier (the 13th page) A4 =-0.17119x10-4 A6 =-0.77526x10-7 A8 =-0.61292x10-9 (the 14th page) A4 =-0.47301x10-6 A6 =-0.11792x10-6 A8 =-0.11550x10-8 A4 (17th page) =-0.62049x10-4 A6=-0.19478x10-7 A8 =-0.39877x10-9f 9.304 25.457 71.964D1 1.5000 22.7213 39.7359 D2 39.7305 18.5090 1.5000D3 9.1586 5.3246 6.90501/(nud)1n=0.031, 1/() [ nud ] 1p=0.011 and 1(deltathetagd) n=0.002 (deltathetagd) 1p=0.049, 1/() [ nud ] 2n=0.017 and 1/(nud)2p=0.048 (deltathetagd) 2n=-0.003, 2(deltathetagd) p=0.036, 1/(nud)34n =0.023 1/(nud)34p =0.014, and 34(deltathetagd) n =-0.000 (deltathetagd) 34p=0.027 (), [ ne ] 34p =1.571, phi1/phiW =0.134|phi2/phiW |=0.598, phi3/phiW =0.208, phi4/phiW =0.319 |phi42/phiW |=0.423, and |phi42/phi41|=0.686 [0072] Example 6f=9.015 -25.458-72.000 F/2.0 2omega=50.789 degree-18.205 degree-6.307 **r1 =140.8301 d1 =2.5000 n1 =1.81264 nu1 =25.43 deltathetagd=0.0165r2 =78.8473 d2 =1.0000r3 =106.3821 d3 =4.1253 n2 =1.43985 nu2 =94.97 deltathetagd=0.0622r4 =-248.1614 d4 =0.1500r5 =47.1352 d5 =5.8436 n3 =1.43985 nu3 =94.97 deltathetagd=0.0622r6 =620.9556 d6 =0.1500r7 =33.7548 d7 =4.0084 n4=1.43985 nu4 =94.97 deltathetagd=0.0622r8 =60.1247 d8 =D1 (adjustable)
r9 =67.2809 d9 =1.5000 n5 =1.60548 nu5 =60.70 deltathetagd=-0.0032 r10=14.5860 d10=11.3750 r11=-19.6696 d11=1.5000 n6 =1.60548 nu6 =60.70 deltathetagd=-0.0032 r12=20.4105 d12=0.1500r13=20.6872 d13=4.0032 n7 =1.84281 nu7 =21.00 deltathetagd=0.0356r14=67.4603 d14=D2 (adjustable)
r15=infinity (diaphragm)
r16=155.3540 d16=2.5000 n8 =1.57098 nu8 =71.30 deltathetagd=0.0266r17=-34.2982 d17=0.1500r18=14.8060 d18=2.5000 n9 =1.57098 nu9 =71.30 deltathetagd=0.0266r19=-191.1452 d19=0.8527r20=-27.3848 d20=1.2000 n10=1.80642 nu10=34.97 deltathetagd=0.0003r21=50.6393 d21=D3 (adjustable)
r22=65.3893 d22=2.8000 n11=1.57098 nu11=71.30 deltathetagd=0.0266r23=-19.3708 d23=0.1500r24=20.3762 d24=7.0318 n12=1.57098 nu12=71.30 deltathetagd=0.0266r25=-111.1751 d25=0.9735r26=-17.4860 d26=1.2000 n13=1.85649 nu13=32.28 deltathetagd=0.0022r27=-109.6380 f 9.01525.458 72.000D1 1.400018.9748 32.8362 D2 33.798715.3195 2.3984D3 7.0203 4.9939 8.19181/(nud)1n=0.039, 1/() [ nud ] 1p=0.011 and 1(deltathetagd) n=0.017 (deltathetagd) 1p=0.062, 1/() [ nud ] 2n=0.017 and 1/(nud)2p=0.048 (deltathetagd) 2n=-0.003, 2(deltathetagd) p=0.036, 1/(nud)34n =0.030 1/(nud)34p =0.014, and 34(deltathetagd) n =0.001 (deltathetagd) 34p =0.027 (), [ ne ] 34p =1.571, phi1 / phiW = 0.144|phi2/phiW |=0.695, phi3/phiW =0.209, phi4/phiW =0.387 |phi42/phiW |=0.369, and |phi42/phi41|=0.596 However, r1 and r2 ... Radius of curvature of lens each side, d1 and d2 ... The main thickness of each lens and lens spacing, n1, and n2 ... The refractive index of e line of each lens, nu 1, and nu 2 ... It is the Abbe number of d line of each lens.
[0073] The 1st lens group which an example 1 is a configuration as shown in drawing 1 , it has forward refractive power and is immobilization on the occasion of zooming

sequentially from a body side, The 2nd lens group which has negative refractive power, moves in monotone on the occasion of zooming in an optical-axis top, and has a variable power function, It is the lens system which has forward refractive power and consists of the 3rd lens group which is immobilization, and the 4th lens group which has forward refractive power, moves forward and backward on the occasion of zooming in an optical-axis top, and adjusts an image surface location on the occasion of zooming. A **** lens group consists of the negative meniscus lens by which the 1st lens group turned the convex to the body side sequentially from the body side, a biconvex lens which turned the field of the strong one of forward refractive power to the body side, and two forward meniscus lenses which turned the convex to the body side. The 2nd lens group consists of the negative meniscus lens and biconcave lens which turned the convex to the body side, and a forward meniscus lens which turned the convex to the body side in order [ side / body ]. The 3rd lens group in order [ side / body ] A diaphragm, It consists of the forward meniscus lens which turned the convex to the image side, a biconvex lens which turned the field of the strong one of forward refractive power to the body side, and a biconcave lens which turned the field of the strong one of negative refractive power to the body side. The 4th lens group consists of the biconvex lens which turned the field of the strong one of forward refractive power to the image side, a biconvex lens which turned the field of the strong one of forward refractive power to the body side, and a negative meniscus lens which turned the convex to the image side sequentially from the body side.
[0074] The aberration situation of the zoom lens of this example 1 is as being shown in drawing 7 , drawing 8 , and drawing 9 , and it turns out that it has very high optical-character ability though it is an easy configuration, and especially chromatic aberration is amended good.
[0075] An example 2 is a configuration as shown in drawing 2 , and is the lens system of the same configuration as an example 1. The plate arranged between the lens system and the image pick-up side in drawing 2 expresses optical elements, such as a color filter and a low pass filter.
[0076] The aberration situation of this example 2 is as being shown in drawing 10 , drawing 11 , and drawing 12 .
[0077] The 1st lens group which an example 3 is the lens configuration shown in drawing 3 , it has forward refractive power and is immobilization on the occasion of zooming sequentially from a body side, The 2nd lens group which has negative refractive power, moves in monotone on the occasion of zooming in an optical-axis top, and has a variable power function, It has forward refractive power and consists of the 3rd lens group which is immobilization, and the 4th lens group which has forward refractive power, moves forward and backward on the occasion of zooming in an optical-axis top, and adjusts an image surface location on the occasion of zooming. A **** 1 lens group the negative meniscus lens which turned the convex to the body side, and the biconvex lens which turned the field of the strong one of forward

refractive power to the body side in order [ side / body ] Lamination ************, It consists of a forward meniscus lens which turned the convex to the body side. The 2nd lens group It consists of the biconcave lens which turned the field of the strong one of negative refractive power to the image side, a biconcave lens, and a forward meniscus lens which turned the convex to the body side sequentially from a body side. The 3rd lens group Sequentially from a body side, a diaphragm, and the biconvex lens and biconcave lens which turned the field of the strong one of forward refractive power to the body side are consisted of lamination ************. The 4th lens group The cemented lens which joined the forward meniscus lens which turned the convex to the body side, and the negative meniscus lens and negative biconvex lens which turned the convex to the body side sequentially from the body side, It consists of a negative meniscus lens which turned the convex to the body side, and the 13th page and the 16th page are the aspheric surfaces of the configuration expressed with the following formula.

[0078] However, the direction of an optical axis is taken in the direction of the direction y-axis perpendicular to an optical axis for the direction of the z-axis. Moreover, r is the paraxial radius of curvature of the aspheric surface, and K is a cone constant and ai. It is an aspheric surface multiplier.

[0079] When the aspheric surface is used for the lens system of this example 3, in the example, an optical overall length is about 100mm to being what increased the degree of freedom of aberration amendment and shortened the overall length of a lens system, and examples 1 and 2 being [ an overall length ] about 120mm.

[0080] The aberration situation of this example 3 is as being shown in drawing 13 , drawing 14 , and drawing 15 .

[0081] With a configuration as shown in drawing 4 , in order [ side / body ], an example 4 has forward refractive power and faces it zooming. The 1st lens group of immobilization, The 2nd lens group which has negative refractive power, moves in monotone on the occasion of zooming in an optical-axis top, and has a variable power function, It has forward refractive power and consists of the 3rd lens group of immobilization, and the 4th lens group which has forward refractive power, moves forward and backward on the occasion of zooming in an optical-axis top, and adjusts an image surface location on the occasion of zooming. And the cemented lens with which the 1st lens group stuck the negative meniscus lens which turned the convex to the body side, and the biconvex lens which turned the field of the strong one of forward refractive power to the body side sequentially from the body side, It consists of two forward meniscus lenses which turned the convex to the body side. The 2nd lens group It consists of the negative meniscus lens which turned the convex to the body side, a biconvex lens, and a forward meniscus lens which turned the convex to

the body side sequentially from a body side. The 3rd lens group The negative meniscus lens which turned the diaphragm and the convex to the image side sequentially from the body side, It consists of a cemented lens which joined the biconvex lens which turned the field of the strong one of forward refractive power to the body side, and the negative meniscus lens which turned the convex to the image side. The 4th lens group It consists of a cemented lens which joined the positive lens which turned the field of the strong one of forward refractive power to the image side, the negative meniscus lens which turned the convex to the body side, and the biconvex lens sequentially from the body side, and a negative meniscus lens which turned the convex to the body side, and the 15th page and the 20th page are the aspheric surfaces.

[0082] Although this example 4 was the same specification as an example 3, it especially increases the number of sheets of the positive lens of the 1st lens group, controls generating of the distortion aberration in a wide angle edge, and amended the spherical aberration and comatic aberration which are generated by the 1st lens group by this by arranging two negative lenses in the 3rd lens group.

[0083] The aberration situation of this example 4 is as being shown in drawing 16 , drawing 17 , and drawing 18 .

[0084] An example 5 is as being shown in drawing 5 . In an example 3 The biconvex lens with which the 3rd lens group turned the diaphragm and the field of the strong one of forward refractive power to the body side sequentially from the body side, It consists of a biconcave lens which turned the field of the strong one of negative refractive power to the body side. A **** 4 lens group sequentially from a body side A biconvex lens, It is [ convex / lamination ************ and ] different at the point which consists of a negative meniscus lens towards a body side in the negative meniscus lens and negative biconvex lens which turned the convex to the body side. Moreover, in this example 5, the 3rd page, the 13th page, the 14th page, and the 17th page, is the aspheric surfaces.

[0085] As compared with the example 3, the fluctuation of the spherical aberration applied to a tele edge from a wide angle edge, comatic aberration, astigmatism, etc. of this example 5 has decreased further by having increased the number of the aspheric surfaces.

[0086] The aberration situation of an example 5 is as being shown in drawing 19 , drawing 20 , and drawing 21 .

[0087] The point that an example 6 is the lens system of a configuration of being shown in drawing 6 , and the 3rd lens group and the 4th lens group move on the occasion of both zooming in an optical-axis top, and are amending the image surface location, The 3rd lens group is different from the example 1 in the point which consists of a diaphragm, the biconvex lens which turned the field of the strong one of forward refractive power to the image side, a biconvex lens which turned the field of the strong one of forward refractive power to the body side, and a biconcave lens

which turned the field of the strong one of negative refractive power to the body side in order from the body side. This example shortened the overall length of a lens system as compared with the example 1, without having made aberration amendment capacity into size and using the aspheric surface like an example 2 thru/or 4 by having increased the movable group.
[0088] The aberration situation of an example 6 is as being shown in drawing 22 , drawing 23 , and drawing 24 .
[0089] In this invention, it is the lens system to which what was indicated by following each term besides the lens system indicated by the claim attains the purpose of invention.
[0090] (1) The zoom lens which is immobilization on an optical axis in case the 1st lens group and the 3rd lens group are variable power in the lens system indicated by claims 1 and 2 of a claim, or 3.
[0091] (2) The zoom lens to which the 4th lens group moves an optical-axis top as a whole by the lens system indicated by the term of the above (1) for image position amendment.
[0092] (3) the lens system indicated by claim 1 of a claim, 2, the above (1), or the term of (2) -- the following conditions (14) thru/or either of (17) -- independent -- or the zoom lens satisfied as two or more combination.
(14) $0.10<phi1/phiW<0.21$ (15) $0.54<|phi2/phiW|<0.76$ (16) $0.10<phi3/phiW<0.26$ (17) $0.26<phi4/phiW<0.45$[0093] (4) The zoom lens with which the 4th lens group consists of the 41st lens group of forward refractive power, and the 42nd lens group of negative refractive power and with which it is satisfied with the lens system indicated by claim 3 of a claim, the above (1), or the term of (2) of following conditions (18) and/or conditions (19).
(18) $0.19<|phi42/phiW|<0.48$ (19) $0.38<|phi42/phi41|<0.74$[0094] (5) The zoom lens which is satisfied with the lens system indicated by the term of the above (4) of conditions (14) thru/or (17).
(14) $0.10<phi1/phiW<0.21$ (15) $0.54<|phi2/phiW|<0.76$ (16) $0.10<phi3/phiW<0.26$ (17) $0.26<phi4/phiW<0.45$[0095] (6) The zoom lens which is satisfied with the lens system indicated by claim 1 of a claim, the above (1), or (2) of the following conditions (4) thru/or (7).
(4) $0.014<1/(nud)2n<0.017$ (5) $-0.01<(deltathetagd)2n<0.01$ (6) $0.030<1/(nud)2p$ (7) $0.015<(deltathetagd) 2p$ [0096] (7) The zoom lens which is satisfied with the lens system indicated by the term of (claim 1 of a claim, 2, the above (1) and (2), or 4) of the following conditions (8) thru/or (11).
(8) $0.020<1/(nud)34n<0.033$ (9) $-0.01<(deltathetagd)34n<0.01$ (10) $0<1/(nud)34p<0.0166$ (11) $0.02<(deltathetagd) 34p$ [0097]
[Effect of the Invention] The zoom lens of this invention can be made to a small lens system by the optimal high optical-character ability for the electronic camera using the image sensor with many pixels suitable for the application which captures the

electronic camera using the camera tube, a solid state image sensor, etc., especially a highly minute image in recent years, though it is a comparatively easy zoom configuration.

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing showing the configuration of the example 1 of this invention

[Drawing 2] Drawing showing the configuration of the example 2 of this invention

[Drawing 3] Drawing showing the configuration of the example 3 of this invention

[Drawing 4] Drawing showing the configuration of the example 4 of this invention

[Drawing 5] Drawing showing the configuration of the example 5 of this invention

[Drawing 6] Drawing showing the configuration of the example 6 of this invention

[Drawing 7] The aberration curve Fig. in the wide angle edge of the example 1 of this invention

[Drawing 8] The aberration curve Fig. in the middle focal distance of the example 1 of this invention

[Drawing 9] The aberration curve Fig. in the tele edge of the example 1 of this invention

[Drawing 10] The aberration curve Fig. in the wide angle edge of the example 2 of this invention

[Drawing 11] The aberration curve Fig. in the middle focal distance of the example 2 of this invention

[Drawing 12] The aberration curve Fig. in the tele edge of the example 2 of this invention

[Drawing 13] The aberration curve Fig. in the wide angle edge of the example 3 of this invention

[Drawing 14] The aberration curve Fig. in the middle focal distance of the example 3 of this invention

[Drawing 15] The aberration curve Fig. in the tele edge of the example 3 of this invention

[Drawing 16] The aberration curve Fig. in the wide angle edge of the example 4 of this invention

[Drawing 17] The aberration curve Fig. in the middle focal distance of the example 4 of this invention

[Drawing 18] The aberration curve Fig. in the tele edge of the example 4 of this invention

[Drawing 19] The aberration curve Fig. in the wide angle edge of the example 5 of this

invention

[Drawing 20] The aberration curve Fig. in the middle focal distance of the example 5 of this invention

[Drawing 21] The aberration curve Fig. in the tele edge of the example 5 of this invention

[Drawing 22] The aberration curve Fig. in the wide angle edge of the example 6 of this invention

[Drawing 23] The aberration curve Fig. in the middle focal distance of the example 6 of this invention

[Drawing 24] The aberration curve Fig. in the tele edge of the example 6 of this invention

[Drawing 25] thetagd-nud Graph

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(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（A）　(11)特許出願公開番号

特開平8－248317

(43)公開日　平成8年(1996)9月27日

| (51)Int.Cl.$^6$ | 識別記号 | 庁内整理番号 | F I | 技術表示箇所 |
|---|---|---|---|---|
| G02B　15/16 | | | G02B　15/16 | |
| 　13/18 | | | 　13/18 | |

審査請求　未請求　請求項の数3　FD　（全22頁）

(21)出願番号　特願平7－79399

(22)出願日　平成7年(1995)3月13日

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(54)【発明の名称】　ズームレンズ

(57)【要約】

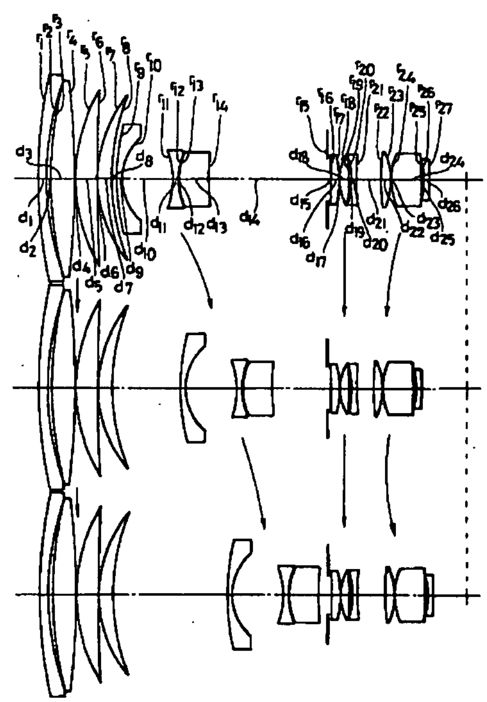
【目的】　本発明は、比較的簡単な構成で、レンズ枚数が少なく、高精細画像を取込む用途に適した画素数の多い撮像素子を用いた電子カメラに最適な高い光学性能特に色収差が良好に補正されたズームレンズを提供するものである。

【構成】　本発明のズームレンズは、物体側から順に、正の第1レンズ群と、、ズーミングの際光軸に沿って可動で変倍作用を有する負の第2レンズ群と、正の第3レンズ群と、正の第4レンズ群とよりなり、第3レンズ群又は第4レンズ群もしくはこれらレンズ群の一部のレンズを用いて変倍時の像位置の変動を補正するようにしたもので、下記条件を満足するレンズ系である。

(1)　$0.25<1/(\nu d)_{1n}<0.04$

(2)　$-0.005<(\Delta\theta gd)_{1n}<0.02$

(3)　$0<1/(\nu d)_{1p}<0.0166$



【特許請求の範囲】

【請求項１】物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングに際して光軸に沿って移動して変倍作用をする第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力の第４レンズ群とよりなり、前記第３レンズ群又は前記第４レンズ群もしくはこれらレンズ群中の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するようにしたレンズ系で、下記の条件（１），（２），（３）を満足するズームレンズ。

（１）　$0.25<1/(\nu_d)_{1n}<0.04$

（２）　$-0.005<(\Delta\theta_{gd})_{1n}<0.02$

（３）　$0<1/(\nu_d)_{1p}<0.0166$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{1n}$は第１レンズ群を構成する負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{1p}$，$(\nu_d)_{1n}$は夫々第１レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【請求項２】物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングの際に光軸に沿って移動して変倍作用をする第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力を持つ第４レンズ群とからなり、前記第３レンズ群又は前記第４レンズ群もしくはそれらレンズ群の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するレンズ系で、下記条件（４），（５），（６），（７）を満足するズームレンズ。

（４）　$0.014<1/(\nu_d)_{2n}<0.017$

（５）　$-0.01<(\Delta\theta_{gd})_{2n}<0.01$

（６）　$0.030<1/(\nu_d)_{2p}$

（７）　$0.015<(\Delta\theta_{gd})_{2p}$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{2p}$，$(\Delta\theta_{gd})_{2n}$は夫々第２レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{2p}$，$(\nu_d)_{2n}$は夫々第２レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【請求項３】物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングに際して光軸に沿って移動して変倍作用をする第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力を持つ第４レンズ群とよりなり、前記第３レンズ群又は前記第４レンズ群もしくはそれらレンズ群の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するレンズ系で、下記条件（８），（９），（１０），（１１）を満足するズームレンズ。

（８）　$0.020<1/(\nu_d)_{34n}<0.033$

（９）　$-0.01<(\Delta\theta_{gd})_{34n}<0.01$

（１０）　$0<1/(\nu_d)_{34p}<0.0166$

（１１）　$0.02<(\Delta\theta_{gd})_{34p}$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{34p}$，$(\Delta\theta_{gd})_{34n}$は第３レンズ群，第４レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{34p}$，$(\nu_d)_{34n}$は夫々第３レンズ群，第４レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、撮像管や固体撮像素子等を用いた電子カメラ特に近年の高精細画像を取込む用途に適している画素数の多い撮像素子を用いた電子カメラに最適な高い光学性能を有するズームレンズに関するものである。

【０００２】

【従来の技術】一般に、電子カメラは撮像面積の小さな撮像管や固体撮像素子を用いて光学像を電子信号に変換するために、これに用いる撮像レンズとしては明るいレンズ系が必要になる。又レンズ系と撮像素子との間に、ローパスフィルターや赤外線カットフィルターなどの光学部材や、ＲＧＢ三原色それぞれの画像をそれぞれの撮像素子で受光するいわゆる多板式電子カメラのように、それぞれの撮像素子に光束を導く、いわゆる色分解プリズム等の光学素子を配置する必要が生じ、焦点距離に比較して大きなバックフォーカスが必要になる。

【０００３】更に、これらカメラにおいては、動画像を撮影する用途が多く、撮影レンズとして高変倍率のズームレンズを用いるのが一般的である。

【０００４】これらの要求を満足するレンズ系として、物体側から順に、正の屈折力を持ちズーミングの際に固定の第１レンズ群と、ズーミングに際して光軸に沿って移動し変動作用を有する負の屈折力を有する第２レンズ群、ズーミングに際して前後に移動して変倍の際の像面の変動を補正して一定に保つ作用を有している第３レンズ群と、ズーミングに際して固定で結像作用を有している正の屈折力を持つ第４レンズ群とよりなる４群ズームレンズが知られている。

【０００５】また近年、カムコーダー用として、物体側から順に、正の屈折力を持ちズーミングに際して固定の第１レンズ群と、ズーミングに際して光軸に沿って移動して変倍作用を有する負の屈折力を持つ第２レンズ群と、ズーミングに際して固定の第３レンズ群と、ズーミングに際して前後に移動して変倍の際の像面の変動を補正して一定に保つ作用と結像作用とを有する正の屈折力を持つ第４レンズ群とよりなる４群ズームレンズや、物

体側から順に、正の屈折力を持ちズーミングの際に固定の第１レンズ群と、ズーミングの際に光軸に沿って移動して変倍作用を有する負の屈折力を持つ第２レンズ群と、ズーミングに際して前後に移動して変倍の際の像面の変動を補正して一定に保つ作用を有する正の屈折力を持つ第３レンズ群と、ズーミングに際して固定で結像作用を有する正の屈折力を持つ第４レンズ群からなる４群ズームレンズ等が知られている。

【０００６】特に、近年の製造技術の発展により、撮像範囲の大きさに比べて画素数の非常に多い固体撮像素子が開発され、例えばハイビジョン映像のように高精細な画像を得ることが可能になった。そのために、撮像レンズも、この撮像素子の性能を十分に引き出し得るような極めて高い光学性能を有するズームレンズが必要になって来た。又、固体撮像素子が小型になり、例えば固体撮像素子の各画素の大きさが小さくなる程、高い解像力が必要になり、撮像レンズ系に対する光学性能の要求はますます高くなって来ている。

【０００７】このような要求を満足するズームレンズとして、特開昭６２－１５３９１３号や特開平１－１２６６１４号、特開平６－５６４５３号、特開平６－１７５０２２号の各公報に記載されている従来例が知られている。

【０００８】

【発明が解決しようとする課題】一般に、高い光学性能を得るためには、光線をできるだけ少しづつ多くの回数屈折させて結像させることにより、各屈折面での収差の発生量が少なくなるようにすることが考えられるが、この場合、必然的に多くの枚数のレンズが必要になり、その結果、レンズ系が大型になる欠点があった。

【０００９】また、ズームレンズの場合、可動群が多いために、ズーミングに伴う収差変動が生ずる。そのため、理想的には、各レンズ群において、収差が良好に補正されていれば、ズーミングの際の収差変動は生じないが、広角端から望遠端にかけて、レンズ系中の光線の通り方は、必ずしも一定ではないため、若干の収差が残存する。ズームレンズにおいて、高い光学性能を達成しようとすると、この残存収差による収差変動を無視することが出来ない。そのために、ズームレンズにおいては、構成するレンズ枚数を増やして広角端から望遠端にかけてレンズ群を複雑な移動をさせて、収差変動を補正するようにするので大型化する。

【００１０】一方、近年ハイビジョン等の高精細画像を取込むカメラが一般化し、多くの分野で利用されるようになり、様々な条件下で利用する必要性から撮影カメラやレンズ系を小型化する要求が強くなっている。そのために、出来るだけ少ないレンズ枚数で、簡単な群構成であって、しかもより高い光学性能にしなければならない。しかしレンズ枚数を少なくすると、球面収差等の単色収差は、非球面レンズを採用する等の手段により補正が可能であるが、少ない枚数のレンズの組合わせによって色収差を良好に補正することは極めて困難である。

【００１１】前述の従来のズームレンズのうち、特公昭６２－１５３９１３号、特開平１－１２６６１４号、特開平６－５６４５３号公報等に記載されているズームレンズは、高精細な画像を取込むために、高い光学性能を達成したレンズ系であるが、例えば特開平１－１２６６１４号公報に記載されているレンズ系は２つのコンペンセータを含む５つのレンズ群からなり、レンズ群数の多い複雑な構成であると共に移動形式も複雑である。又、特開平６－１７５０２２号公報に記載されたレンズ系は４群構成であるが、軸上色収差がまだ十分に補正されているとはいえない。

【００１２】本発明は比較的簡単な構成であって、レンズ枚数が少なく、又撮像管や固体撮像素子等を用いた電子カメラ、特に近年の高精細画像を取込む用途に適した画素数の多い撮像素子を用いた電子カメラに最適な高い光学性能、特に色収差を良好に補正した小型なズームレンズを提供することにある。

【００１３】

【課題を解決するための手段】本発明のズームレンズは、物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングに際して光軸に沿って移動して変倍作用をする第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力の第４レンズ群とよりなり、前記第３レンズ群又は前記第４レンズ群もしくはこれらレンズ群中の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するようにしたレンズ系で、下記の条件（１），（２），（３）を満足することを特徴としている。

【００１４】

（１）　$0.25 < 1/(\nu_d)_{1n} < 0.04$

（２）　$-0.005 < (\Delta\theta_{gd})_{1n} < 0.02$

（３）　$0 < 1/(\nu_d)_{1p} < 0.0166$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{1n}$は第１レンズ群を構成する負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{1p}$，$(\nu_d)_{1n}$は夫々第１レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【００１５】図２５は、$\theta_{gd}-\nu_d$グラフで、線Ａがこのグラフ上でのＫ７とＦ２とを結ぶ線である。この図には示していないが、周知のように普通のガラスの多くはほぼこの線に従って分布している。

【００１６】ここで$\Delta\theta_{gd}$は、前記のように$\theta_{gd}-\nu_d$のグラフ中でＫ７（$n_d=1.51112$、$\nu_d=60.5$）とＦ２（$n_d=1.62004$、$\nu_d=36.3$）のグラフ上の点を結んだ線からの上下方向（縦軸方向）のずれ量を表わしている。即ち図２５に示す点Ｋ７

と点Ｆ２を結んだ線Ａを上方又は下方に$\Delta\theta_{gd}$の値だけ平行移動した線を示している。したがって、条件（２）の上限の$\Delta\theta_{gd}$＝０．０４は、線$A_1$、又下限の$\Delta\theta_{gd}$＝０．０２５は線$A_2$に当る。又条件（１）は、逆数にすれば４０＞$(\nu_d)_{1n}$＞２５になり、上限はグラフ上で線$B_1$、下限はグラフ上で線$B_2$となる。したがって、条件（１），（２）を合わせると、線$A_1$，$A_2$，$B_1$，$B_2$で囲まれた斜線部分が条件（１），条件（２）の範囲内である。つまり本発明では、第１レンズ群中の負レンズが、平均すると前記斜視の範囲内に含まれることを意味している。

【００１７】又本発明のズームレンズの第２の構成のレンズ系として次のものがある。即ち、物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングの際に光軸に沿って移動して変倍作用を第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力を持つ第４レンズ群とからなり、前記第３レンズ群又は前記第４レンズ群もしくはそれらレンズ群の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するレンズ系で、下記条件（４），（５），（６），（７）を満足するズームレンズである。

【００１８】

（４）　$0.014 < 1/(\nu_d)_{2n} < 0.017$

（５）　$-0.01 < (\Delta\theta_{gd})_{2n} < 0.01$

（６）　$0.030 < 1/(\nu_d)_{2p}$

（７）　$0.015 < (\Delta\theta_{gd})_{2p}$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{2p}$，$(\Delta\theta_{gd})_{2n}$は夫々第２レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{2p}$，$(\nu_d)_{2n}$は夫々第２レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【００１９】更に本発明のズームレンズの第３の構成のレンズ系として次に述べるものもある。即ち、物体側から順に、正の屈折力を持つ第１レンズ群と、負の屈折力を持ちズーミングに際して光軸に沿って移動して変倍作用をする第２レンズ群と、正の屈折力を持つ第３レンズ群と、正の屈折力を持つ第４レンズ群とよりなり、前記第３レンズ群又は前記第４レンズ群もしくはそれらレンズ群の一部のレンズを用いて前記第２レンズ群の移動による変倍時の像面位置の変動を補正するレンズ系で、下記条件（８），（９），（１０），（１１）を満足するズームレンズ。

【００２０】

（８）　$0.020 < 1/(\nu_d)_{34n} < 0.033$

（９）　$-0.01 < (\Delta\theta_{gd})_{34n} < 0.01$

（１０）　$0 < 1/(\nu_d)_{34p} < 0.0166$

（１１）　$0.02 < (\Delta\theta_{gd})_{34p}$

ただし$\Delta\theta_{gd}$は硝材のｄ線のアッベ数を$\nu_d$としｇ線，ｄ線に対する部分分散比を$\theta_{gd}$とするとき$\theta_{gd}-\nu_d$グラフ上でＫ７とＦ２とを結ぶ直線からの縦座の差、$(\Delta\theta_{gd})_{34p}$，$(\Delta\theta_{gd})_{34n}$は第３レンズ群，第４レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\Delta\theta_{gd}$の平均値、$(\nu_d)_{34p}$，$(\nu_d)_{34n}$は夫々第３レンズ群，第４レンズ群を構成する正レンズおよび負レンズに用いる硝材の$\nu_d$の平均値である。

【００２１】カムコーダー用ズームレンズ等の小型なズームレンズを達成するためには、前述のように、物体側から順に、正の屈折力を持ちズーミングに際して固定の第１レンズ群と、ズーミングに際して光軸に沿って移動して変倍作用を有する負の屈折力を持つ第２レンズ群と、ズーミングに際して固定の第３レンズ群と、ズーミングの際に前後に移動して変倍による像面の変動を補正して一定に保つ作用と結像作用とを有する正の屈折力を持つ第４レンズ群とからなる４群ズームレンズや、物体側から順に、正の屈折力を持ちズーミングの際固定の第１レンズ群と、ズーミングの際に光軸に沿って移動し、変動作用を有する負の屈折力を持つ第２レンズ群と、ズーミングに際し前後に移動して変倍の際の像面の変動を補正して一定に保つ作用を有し正の屈折力を持つ第３レンズ群と、ズーミングの際固定であって結像作用を有し正の屈折力を持つ第４レンズ群とからなる４群ズームレンズがある。

【００２２】これら従来のズームレンズは、簡単な構成であり、しかも可動群を動かすスペースを効率よく確保した小型化に適したズームタイプであるが、小型化を図るために各レンズ群の構成枚数を少なくして屈折力を強くしているために収差変動が大になる欠点がある。

【００２３】そのため、非球面レンズを用いて収差補正を行なうようにした従来例が増えている。しかし非球面レンズは、単色収差の補正には効果があるが、色収差を補正する能力はなく、単に非球面レンズを用いるだけでは高精細画像を取り込む結像レンズとして要求される光学性能を達成できない。前記のような構成枚数の少ないレンズ系にて色収差を十分良好に補正するためには、使用する硝材を、光学特性を十分考慮して選択する必要がある。

【００２４】特に銀塩カメラや電子カメラ等は、色収差の補正対象となる波長が広範囲にわたり、いわゆる２次スペクトルの補正が極めて重要になり、使用する硝材の光学特性も屈折率とアッベ数のみならず異常分散特性を十分に考慮しなければならない。更にＣ線およびＦ線の色収差を補正する１次の色収差と２次スペクトルの補正や、色収差の補正と単色収差の補正とは矛盾する場合が多く、両者を良好に補正することは困難である。

【００２５】本発明は、レンズ材料として使用する硝材の光学特性を検討し、単色収差や１次の色収差、２次ス

ペクトル等を良好に補正したものである。

【００２６】本発明のズームレンズにおいて、第１レンズ群は、広角端から望遠端にかけて、レンズ系を通過する光線の挙動が大きく変動するため、特に第１レンズ群単独で諸収差が十分補正されていなければならない。色収差を補正する観点から考えると、第１レンズ群は、正の屈折力を有するので、負レンズには高分散の硝材を、正レンズには低分散の硝材を用いる必要がある。しかし、このような硝材の組合わせによる色収差の補正は、１次の色消し即ち、Ｃ線とＦ線とで発生する色収差を等しくする補正であり、２次スペクトルの補正には有効ではなく、更に硝材が限定される。

【００２７】本発明のズームレンズのように、銀塩カメラや電子カメラ等の撮影レンズは、通常ｇ線などの短波長域での２次スペクトルが問題となり、１次の色収差を補正するためにｇ線に対する色収差は大きく正方向に発生する。したがって、２次スペクトルを補正するためには、ｇ線に対する色収差を負の方向に戻す必要がある。そのためには、正レンズのｇ線に対する屈折率を相対的に高くするか、あるいは負レンズのｇ線に対する屈折率を相対的に低くすればよい。

【００２８】ここで、硝材の短波長域での異常分散性を示す$\Delta\theta_{gd}$を考えると、ｇ線の屈折率を相対的に高くするためには、$\Delta\theta_{gd}$の値を大にし又ｇ線の屈折率を相対的に低くするためには、$\Delta\theta_{gd}$の値を小にすればよい。つまり、正レンズは、$\Delta\theta_{gd}$の値を大にし、負レンズは$\Delta\theta_{gd}$の値を小にすればよい。この条件は、レンズ系全体の色収差の振る舞いとｇ線に対する屈折率との関係により得られるもので、レンズ群の正負には関係しない。

【００２９】次に、ガラスマップを検討すると、アッベ数の小さい高分散硝材は、$\Delta\theta_{gd}$の値が大でありアッベ数が大きくなるにしたがって$\Delta\theta_{gd}$は減少する。そしておおざっぱに分類すると、おおよそ$\nu_d$ ＝３５近傍で$\Delta\theta_{gd}$は０の近傍の値になり、おおよそ$\nu_d$ ＝６０近傍までの間は$|\Delta\theta_{gd}|$の値の小さないわゆるノーマルガラスと、$\Delta\theta_{gd}$が負の大きな値を持つランタン系ガラスの２種類が分布する。ノーマルガラスは、おおよそ$\nu_d$ ＝７０近辺まで存在するが、おおよそ$\nu_d$ ＝６３近辺から大きな値になると$\Delta\theta_{gd}$の値の大きないわゆる異常分散ガラスが分布するようになる。

【００３０】本発明のレンズ系において、第１レンズ群中の負レンズは、１次の色補正のためには高分散硝材を用いるのが好ましいが、高分散硝材は$\Delta\theta_{gd}$が大になりすぎるため２次スペクトルの補正には不適当である。又第１レンズ群の正レンズに用いる硝材としては、低分散で$\Delta\theta_{gd}$の値が大きいいわゆる異常分散ガラスが適しているが、屈折率が低くなるために他の単色収差の補正が困難になる。

【００３１】以上の点を考え、本発明のズームレンズは、第１レンズ群を前記の条件（１），（２），（３）を満足するようにした。

【００３２】条件（１）の上限を越えると負レンズの分散が大きくなり、１次の色補正にとっては好ましいが、２次スペクトルを補正するための条件である条件（２）を満足する硝材を選択することが困難になる。また条件（１）の下限を越えると負レンズの分散が小になり、１次の色補正が困難になり、特に広角端における倍率の色収差が大きく残存することになる。

【００３３】条件（２）の上限を越えると、負レンズの異常分散性が逆方向に動き、特に望遠端での軸上色収差の補正が困難になり、下限を越えると条件（１）を満足する硝材が得られなくなる。

【００３４】条件（３）の上限を越えると正レンズに用いる硝材としては分散が大きくなりすぎて、広角端での倍率の色収差の補正が困難になる。

【００３５】上記のズームレンズにおいて、２次スペクトルの補正を一層良好にするためには、次の条件（１２）を満足することが望ましい。

【００３６】（１２）　　$0.02<(\Delta\theta_{gd})_{1p}$

ここで$(\Delta\theta_{gd})_{1p}$は第１レンズ群の正レンズの$\Delta\theta_{gp}$の平均値である。

【００３７】この条件（１２）の下限を越えると正レンズでの２次スペクトルの補正効果が十分に得られず高度な色補正が困難になる。

【００３８】第１レンズ群の正レンズによる２次スペクトルの補正作用を一層増大せしめるためには、下記条件（１２′）を満足することが好ましい。

（１２′）　　$0.03<(\Delta\theta_{gd})_{1p}$

【００３９】本発明のズームレンズの第１レンズ群は、広角端においては広い画角の軸外光線を又、望遠端においては光線高の高い軸上光線を滑らかに曲げて第２レンズ群へ導く必要がある。そのために、この第１レンズ群は、物体側より順に、物体側に凸面を向けた負のメニスカスレンズと少なくとも２枚の正レンズとから構成し、更に像側の正レンズを物体側に凸面を向けた正のメニスカスレンズにすることが望ましい。

【００４０】更に、前記の第１レンズ群の少なくとも２枚の正レンズのうち物体側の正レンズは、メニスカス形状もしくは両凸形状で屈折力を強くすることが好ましい。ここで単色収差特にペッツバール和を良好に補正するためには、物体側の正レンズの屈折率を像側の正レンズの屈折率と同じかもしくは高くすることが望ましい。

【００４１】次に本発明のズームレンズにおいて、第２レンズ群は負の屈折力のレンズ群であり、主として変倍を担当するレンズ群であるので、その屈折力が大にあって、しかもズーミングに際して大きく移動するので、収差変動が問題になる。そこで、第２レンズ群での特に単色収差の発生を抑えるためには、負レンズの枚数を増やして負の屈折力を分散させることが好ましい。しかし色収差を考えると特に広角端における負の倍率の色収差の

発生が大であってその補正が極めて難しくなる。したがって、第２レンズ群は、物体側から順に、像側に負の屈折力の強いほうの面を向けた負レンズと、負レンズと、物体側に正の屈折力との強い方の面を向けた正レンズにて構成し、使用する硝材を適切に選択するのが好ましい。

【００４２】この第２レンズ群は、負の屈折力を持つために、第１レンズ群とは逆の構成つまり負レンズには低分散の硝材を、正レンズには高分散の硝材を配置することが１次の色消し条件になる。しかし２次スペクトルの補正のためには、第１レンズ群と同じように正レンズには$\Delta\theta_{gd}$を大きく又負レンズには$\Delta\theta_{gd}$を小さくすることが好ましい。

【００４３】これらの点を考慮して適切な硝材を検討した結果、前掲の条件（４），（５），（６），（７）を満足することが望ましいことを見出した。

【００４４】条件（４）の上限を越えると負レンズの分散が大になりすぎて１次の色補正が困難になり、広角端における倍率の色収差や望遠端における軸上色収差を同時に補正することが困難になる。また下限を越えると負の分散が小さくなりすぎてこのレンズ群での２次スペクトルの補正のための条件（５）を満足する硝材の選択が難しくなる。

【００４５】条件（５）の上限を越えると２次スペクトルの補正効果が減少するとともに、使用出来る硝材が低屈折率又は高分散の硝材に限定される。前者の低分散の硝材の場合、負レンズで発生する負のペッツバール和が大になりすぎて像面湾曲が補正できなくなり、又後者の高分散の硝材の場合、１次の色補正が困難になる。又条件（５）の下限を越えると屈折率の高いランタン系の硝材に限定されて分散が大きくなり、１次の色補正が不十分になる。

【００４６】条件（６）の下限を越えると正レンズの分散が小さくなり、１次の色補正が不十分で、広角端における倍率の色収差や望遠端における軸上色収差を同時に補正することが困難になる。

【００４７】条件（７）の下限を越えると条件（６）を満足する硝材の選択が困難になる。

【００４８】第２レンズ群において正レンズによる２次スペクトルの補正効果を高めるためには、条件（７′）、更に高めるためには条件（７″）を満足することが望ましい。

（７′）　　$0.020<(\Delta\theta_{gd})_{2p}$

（７″）　　$0.025<(\Delta\theta_{gd})_{2p}$

【００４９】更に、本発明のズームレンズにおいて、第３レンズ群と第４レンズ群は、第２レンズ群を射出した発散光束を結像させるレンズ群であって、第３レンズ群又は第４レンズ群、あるいはこれら第３，第４レンズ群の一部のレンズがコンペンセーターの役割を持ち、ズーミングに際して光軸上を前後に移動させる。しかし、これら移動距離は比較的小であるため広角端から望遠端にかけての収差の発生状況は比較的安定している。

【００５０】これら第３レンズ群，第４レンズ群は、いずれも正のレンズ群であるため、第１レンズ群と同様の考えで収差補正を行なえばよいが、第３，第４レンズ群は、結像レンズ群であるため正の屈折力が強く色収差以外の収差特にペッツバール和に及ぼす影響を考慮しなければならない。この点を考慮して第３，第４レンズ群に関して硝材を検討した結果、前掲の条件（８），（９），（１０），（１１）を満足することが望ましいことを見出した。

【００５１】条件（８）の上限を越えると負レンズの分散が大きくなり１次の色補正には有利であるが、条件（９）を満足する$\Delta\theta_{gd}$の硝材を選択することが困難になる。また条件（８）の下限を越えると負レンズの分散が小さくなり、１次の色補正が困難になり、広角端における倍率の色収差と望遠端における軸上色収差を同時に補正することが困難になる。

【００５２】条件（９）の上限を越えると２次スペクトルを補正する方向とは逆方向になり、又下限を越えると条件（８）を満足する硝材を得ることが困難になる。

【００５３】条件（１０）の上限を越えると正レンズの分散が大きくなりすぎて１次の色補正が困難になり広角端における倍率の色収差と望遠端における軸上色収差を同時に補正することが困難である。

【００５４】条件（１１）の下限を越えると２次スペクトルの補正効果が小さくなり、所望の色収差性能が得られない。

【００５５】上記の条件（１０），（１１）を満足する低分散硝材は、屈折率が小さくペッツバールが悪化するおそれがある。これを防ぐために、第４レンズ群を、物体側より順に、正の屈折力を有する第４１レンズ群と負の屈折力を有する第４２レンズ群とにて構成することが好ましい。第４レンズ群をこのような構成にすることによって第２レンズ成分の負の屈折力を増大させてペッツバール和の補正を行なってもこの第２レンズ成分を通過する軸上光線高が低く他の収差への影響を最小にすることが出来る。又ペッツバール和を良好に補正するためには、正レンズの屈折率を出来るだけ高くすることが望ましく具体的には、下記条件（１３）を満足することが望ましい。

【００５６】

（１３）　　$1.48<(n_e)_{34p}<1.65$

ただし、$(n_e)_{34p}$は第３レンズ群，第４レンズ群を構成する正レンズのｅ線での屈折率の平均値である。

【００５７】条件（１３）の上限を越えると条件（１１）を満足する硝材を選択することができなくなり、又下限を越えるとペッツバール和の悪化が著しく、負レンズの屈折力を大きくしても他の収差の悪化を招かずに補正することが出来ない。

【0058】また、倍率の色収差の補正のために第１レンズ群に用いる負レンズに高分散の硝材を用いる必要性が高いときは、第３レンズ群と第４レンズ群での２次スペクトルの補正効果を高めることが望ましい。具体的には、下記条件（9′），（11′）を満足することが望ましい。

【0059】（9′）　$-0.005<(\Delta\theta_{gd})_{34n}<0.005$

（11′）　$0.025<(\Delta\theta_{gd})_{34p}$

本発明レンズ系において、更に収差を良好に補正するためには下記条件（14），（15），（16），（17），（18），（19）を満足することが望ましい。

【0060】

（14）　$0.10<\varphi_1/\varphi_W<0.21$

（15）　$0.54<|\varphi_2/\varphi_W|<0.76$

（16）　$0.10<\varphi_3/\varphi_W<0.26$

（17）　$0.26<\varphi_4/\varphi_W<0.45$

（18）　$0.19<|\varphi_{42}/\varphi_W|<0.48$

（19）　$0.38<|\varphi_{42}/\varphi_{41}|<0.74$

ただし、$\varphi_1$，$\varphi_2$，$\varphi_3$，$\varphi_4$，$\varphi_{41}$，$\varphi_{42}$，は夫々第１レンズ群，第２レンズ群，第３レンズ群，第４レンズ群，第４レンズ群の第１レンズ成分および第４レンズ群の第２レンズ成分の屈折力、$\varphi_W$ は広角端における全系の屈折力である。

【0061】条件（14）の上限を越えて第１レンズ群の屈折力が大になると第２レンズ群の屈折力も大にしないとバランスがとれなくなり、レンズ系のバックフォーカスの確保や全長を短くするためには有利であるが、諸収差特に望遠端での球面収差、コマ収差、非点収差が悪化し他のレンズ群で補正出来ない。又条件（14）の下限を越えて第１レンズ群の屈折力が小になると第３レンズ群や第４レンズ群で発生する軸上色収差や倍率の色収差および球面収差の補正が困難になり特に広角端から中間焦点距離にかけての残存収差が大きくなる。

【0062】条件（15）の上限を越えて第２レンズ群の屈折力が大になると、レンズ系のバックフォーカスの確保と全長を短くするためには有利であるが、正のレンズ群中のいずれかのレンズ群の屈折力を増大させる必要があり、そのため広角端から望遠端にかけての諸収差の変動時に倍率の色収差の変動が大きい。また条件（15）の下限を越えて第２レンズ群の屈折力が小になると変倍比を確保するためには、第２レンズ群の移動距離を大にしなければならずレンズ系が大型になる。更に正のレンズ群で発生する負の球面収差を良好に補正することが困難になり、球面収差の変動が大になる。

【0063】条件（16）の上限を越えて第３レンズ群の屈折力が大になるか、条件（17）の下限を越え第４レンズ群の屈折力が小になると正の屈折力が第３レンズ群に集まり、特に軸上色収差と倍率の色収差の発生の割合いが変化し、広角端から望遠端にかけてバランス良く補正することが困難になり、広角端での倍率の色収差あるいは望遠端において軸上色収差が大きく残存する。ここで色収差の補正を優先させた場合、特にメリディオナル像面の変動が大きくなり補正が困難になる。また条件（16）の下限を越えて第３レンズ群の屈折力が小になるか条件（17）の上限を越えて第４レンズ群の屈折力が大になると正の屈折力が第４レンズ群に集まり、第４レンズ群にて発生する球面収差や軸上色収差が増大し補正が困難になる。

【0064】条件（18）の上限を越えて $|\varphi_{42}/\varphi_W|$ の値が大になるか条件（19）の上限を越えて $|\varphi_{42}/\varphi_{41}|$ の値が大になると、第４レンズ群内における軸上光線に対する補正寄与と軸外光線に対する補正寄与が変化してバランスをとることが困難になり、広角端での色収差、望遠端でのメリディオナル像面湾曲、広角端から中間焦点距離にかけてのコマ収差が大きく残存し好ましくない。逆に条件（18）の下限を越えて $|\varphi_{42}/\varphi_W|$ の値が小さくなるか条件（19）の下限を越えて $|\varphi_{42}/\varphi_{41}|$ の値が小さくなると広角端から望遠端にかけてのメリディオナル像面湾曲と軸上色収差の変動が大きくなる。更に中間焦点距離から望遠端にかけての球面収差が大きく残存し補正することが困難になる。

【0065】更に条件（14）乃至条件（19）においてその上下限の値を下記条件（14′）乃至（19′）に示すようにすれば一層望ましい。

【0066】

（14′）　$0.12<\varphi_1/\varphi_W<0.17$

（15′）　$0.57<|\varphi_2/\varphi_W|<0.73$

（16′）　$0.10<\varphi_3/\varphi_W<0.23$

（17′）　$0.30<\varphi_4/\varphi_W<0.41$

（18′）　$0.22<|\varphi_{42}/\varphi_W|<0.45$

（19′）　$0.41<|\varphi_{42}/\varphi_{41}|<0.70$

更に条件（14），（16），（19）の代りに下記条件（14″），（16″），（19″）を満足することが望ましい。

（14″）　$0.125<\varphi_1/\varphi_W<0.145$

（16″）　$0.17<\varphi_3/\varphi_W<0.23$

（19″）　$0.45<|\varphi_{42}/\varphi_{41}|<0.70$

【0067】

【実施例】次に本発明のズームレンズの各実施例を示す。

実施例１

$f=9.061\sim25.464\sim71.998$　，$F/2.0$

$2\omega=49.947°\sim18.297°\sim6.327°$

$r_1=139.5134$

$d_1=2.5000$ $n_1=1.81264$ $\nu_1=25.43$ $\Delta\theta_{gd}=0.0165$
$r_2=80.9589$
$d_2=1.0000$
$r_3=103.9774$
$d_3=7.2273$ $n_2=1.43985$ $\nu_2=94.97$ $\Delta\theta_{gd}=0.0622$
$r_4=-249.3944$
$d_4=0.1500$
$r_5=48.1566$
$d_5=6.3422$ $n_3=1.43985$ $\nu_3=94.97$ $\Delta\theta_{gd}=0.0622$
$r_6=390.6397$
$d_6=0.1500$
$r_7=36.0540$
$d_7=4.2911$ $n_4=1.43985$ $\nu_4=94.97$ $\Delta\theta_{gd}=0.0622$
$r_8=61.0815$
$d_8=D_1$ （可変）
$r_9=61.5748$
$d_9=1.5000$ $n_5=1.60548$ $\nu_5=60.70$ $\Delta\theta_{gd}=-0.0032$
$r_{10}=15.7087$
$d_{10}=14.9271$
$r_{11}=-21.1656$
$d_{11}=1.5000$ $n_6=1.60548$ $\nu_6=60.70$ $\Delta\theta_{gd}=-0.0032$
$r_{12}=20.7844$
$d_{12}=0.1500$
$r_{13}=20.6360$
$d_{13}=8.6002$ $n_7=1.84281$ $\nu_7=21.00$ $\Delta\theta_{gd}=0.0356$
$r_{14}=57.3063$
$d_{14}=D_2$ （可変）
$r_{15}=\infty$ （絞り）
$d_{15}=1.0000$
$r_{16}=-331.3956$
$d_{16}=2.5000$ $n_8=1.57098$ $\nu_8=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{17}=-32.3660$
$d_{17}=0.1500$
$r_{18}=15.8324$
$d_{18}=2.5000$ $n_9=1.57098$ $\nu_9=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{19}=-158.1052$
$d_{19}=0.8531$
$r_{20}=-26.1704$
$d_{20}=1.5000$ $n_{10}=1.80642$ $\nu_{10}=34.97$ $\Delta\theta_{gd}=0.0003$
$r_{21}=80.3910$
$d_{21}=D_3$ （可変）
$r_{22}=70.0995$
$d_{22}=2.8000$ $n_{11}=1.57098$ $\nu_{11}=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{23}=-20.7695$
$d_{23}=0.1500$
$r_{24}=19.7179$
$d_{24}=8.7237$ $n_{12}=1.57098$ $\nu_{12}=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{25}=-105.4606$
$d_{25}=0.7647$
$r_{26}=-18.6567$

$d_{26}$=1.5000 $n_{13}$=1.85649 $\nu_{13}$=32.28 $\Delta\theta_{gd}$=0.0022
$r_{27}$=-174.0609

| | | | |
|---|---|---|---|
| f | 9.061 | 25.464 | 71.998 |
| $D_1$ | 1.4000 | 19.7747 | 33.1226 |
| $D_2$ | 34.6787 | 16.2987 | 2.9565 |
| $D_3$ | 7.3055 | 4.8140 | 8.0961 |

$1/(\nu_d)_{1n}$=0.039，$1/(\nu_d)_{1p}$=0.011，$(\Delta\theta_{gd})_{1n}$=0.017
$(\Delta\theta_{gd})_{1p}$=0.062，$1/(\nu_d)_{2n}$=0.017，$1/(\nu_d)_{2p}$=0.048
$(\Delta\theta_{gd})_{2n}$=-0.003，$(\Delta\theta_{gd})_{2p}$=0.036，$1/(\nu_d)_{34n}$=0.030
$1/(\nu_d)_{34p}$=0.014，$(\Delta\theta_{gd})_{34n}$=0.001
$(\Delta\theta_{gd})_{34p}$=0.027，$(n_e)_{34p}$=1.571，$\varphi_1/\varphi_W$=0.136
$|\varphi_2/\varphi_W|$=0.691，$\varphi_3/\varphi_W$=0.182，$\varphi_4/\varphi_W$=0.392
$|\varphi_{42}/\varphi_W|$=0.370，$|\varphi_{42}/\varphi_{41}|$=0.609

【0068】実施例2

f=9.046～25.465～71.992，F／2.0
2ω=50.417°～18.243°～6.344°
$r_1$=152.3247
$d_1$=2.5000 $n_1$=1.81264 $\nu_1$=25.43 $\Delta\theta_{gd}$=0.0165
$r_2$=83.1327
$d_2$=1.0000
$r_3$=103.0268
$d_3$=5.5936 $n_2$=1.43985 $\nu_2$=94.97 $\Delta\theta_{gd}$=0.0622
$r_4$=-236.3738
$d_4$=0.1500
$r_5$=48.2477
$d_5$=5.9198 $n_3$=1.43985 $\nu_3$=94.97 $\Delta\theta_{gd}$=0.0622
$r_6$=440.1637
$d_6$=0.1500
$r_7$=34.9932
$d_7$=4.0660 $n_4$=1.43985 $\nu_4$=94.97 $\Delta\theta_{gd}$=0.0622
$r_8$=61.8422
$d_8$=$D_1$（可変）
$r_9$=72.3857
$d_9$=1.5000 $n_5$=1.60548 $\nu_5$=60.70 $\Delta\theta_{gd}$=-0.0032
$r_{10}$=14.5704
$d_{10}$=12.4293
$r_{11}$=-19.9601
$d_{11}$=1.5000 $n_6$=1.60548 $\nu_6$=60.70 $\Delta\theta_{gd}$=-0.0032
$r_{12}$=21.1642
$d_{12}$=0.1500
$r_{13}$=21.0503
$d_{13}$=6.1625 $n_7$=1.84281 $\nu_7$=21.00 $\Delta\theta_{gd}$=0.0356
$r_{14}$=69.8615
$d_{14}$=$D_2$（可変）
$r_{15}$=∞（絞り）
$d_{15}$=1.0000
$r_{16}$=-287.7720
$d_{16}$=2.5000 $n_8$=1.57098 $\nu_8$=71.30 $\Delta\theta_{gd}$=0.0266
$r_{17}$=-30.3056
$d_{17}$=0.1500

$r_{18}$=16.9576
$d_{18}$=2.5000 $n_9$ =1.57098 $\nu_9$ =71.30 $\Delta\theta_{gd}$=0.0266
$r_{19}$=-87.5745
$d_{19}$=2.0057
$r_{20}$=-25.8774
$d_{20}$=1.2000 $n_{10}$=1.80642 $\nu_{10}$=34.97 $\Delta\theta_{gd}$=0.0003
$r_{21}$=66.8633
$r_{22}$=61.9059
$d_{22}$=2.8000 $n_{11}$=1.57098 $\nu_{11}$=71.30 $\Delta\theta_{gd}$=0.0266
$r_{23}$=-21.0746
$d_{23}$=0.1500
$r_{24}$=21.0941
$d_{24}$=7.3060 $n_{12}$=1.57098 $\nu_{12}$=71.30 $\Delta\theta_{gd}$=0.0266
$r_{25}$=-79.5816
$d_{25}$=0.7497
$r_{26}$=-21.1787
$d_{26}$=1.2000 $n_{13}$=1.85649 $\nu_{13}$=32.28 $\Delta\theta_{gd}$=0.0022
$r_{27}$=-356.0244
$d_{27}$=1.0000
$r_{28}$=∞
$d_{28}$=7.0000 $n_{14}$=1.51825 $\nu_{14}$=64.15
$r_{29}$=∞

| | | | |
|---|---|---|---|
| f | 9.046 | 25.465 | 71.992 |
| $D_1$ | 1.4000 | 19.8294 | 33.1916 |
| $D_2$ | 34.3586 | 15.9299 | 2.5658 |
| $D_3$ | 8.2701 | 5.1604 | 7.9118 |

$1/(\nu_d)_{1n}$=0.039， $1/(\nu_d)_{1p}$=0.011， $(\Delta\theta_{gd})_{1n}$=0.017
$(\Delta\theta_{gd})_{1p}$=0.062， $1/(\nu_d)_{2n}$=0.017， $1/(\nu_d)_{2p}$=0.048
$(\Delta\theta_{gd})_{2n}$=-0.003, $(\Delta\theta_{gd})_{2p}$=0.036， $1/(\nu_d)_{34n}$ =0.030
$1/(\nu_d)_{34p}$ =0.014， $(\Delta\theta_{gd})_{34n}$ =0.001
$(\Delta\theta_{gd})_{34p}$ =0.027， $(n_e)_{34p}$ =1.571， $\varphi_1/\varphi_W$ =0.140
$|\varphi_2/\varphi_W|$=0.707， $\varphi_3/\varphi_W$ =0.199， $\varphi_4/\varphi_W$ =0.389
$|\varphi_{42}/\varphi_W|$=0.344， $|\varphi_{42}/\varphi_{41}|$=0.564

【0069】実施例3

f =9.150 ～25.430～71.943 ， F／2.0
2ω=50.125° ～17.851° ～6.284 °
$r_1$ =67.3534
$d_1$ =1.8000 $n_1$ =1.80642 $\nu_1$ =34.97 $\Delta\theta_{gd}$=0.0003
$r_2$ =41.7227
$d_2$ =5.3000 $n_2$ =1.43985 $\nu_2$ =94.97 $\Delta\theta_{gd}$=0.0622
$r_3$ =-310.9797
$d_3$ =0.1000
$r_4$ =36.7193
$d_4$ =3.9573 $n_3$ =1.43985 $\nu_3$ =94.97 $\Delta\theta_{gd}$=0.0622
$r_5$ =204.0192
$d_5$ =$D_1$ （可変）
$r_6$ =-176.6655
$d_6$ =1.0000 $n_4$ =1.65425 $\nu_4$ =58.52 $\Delta\theta_{gd}$=-0.0050
$r_7$ =12.9811
$d_7$ =3.7851

$r_8$ =−24.9700

$d_8$ =1.0000 $n_5$ =1.65425 $\nu_5$ =58.52 $\Delta\theta_{gd}$=−0.0050

$r_9$ =68.5111

$d_9$ =0.2000

$r_{10}$=28.4668

$d_{10}$=2.8000 $n_6$ =1.84281 $\nu_6$ =21.00 $\Delta\theta_{gd}$=0.0356

$r_{11}$=190.5820

$d_{11}$=$D_2$ （可変）

$r_{12}$=∞（絞り）

$d_{12}$=1.1000

$r_{13}$=15.2088 （非球面）

$d_{13}$=3.8000 $n_7$ =1.57098 $\nu_7$ =71.30 $\Delta\theta_{gd}$=0.0266

$r_{14}$=−55.0074

$r_{15}$=37.4721

$d_{15}$=$D_3$ （可変）

$r_{16}$=22.0013 （非球面）

$d_{16}$=2.8000 $n_9$ =1.57098 $\nu_9$ =71.30 $\Delta\theta_{gd}$=0.0266

$r_{17}$=802.9020

$d_{17}$=0.1000

$r_{18}$=24.9962

$d_{18}$=1.0000 $n_{10}$=1.75453 $\nu_{10}$=35.27 $\Delta\theta_{gd}$=0.0036

$r_{19}$=17.2865

$d_{19}$=2.8000 $n_{11}$=1.57098 $\nu_{11}$=71.30 $\Delta\theta_{gd}$=0.0266

$r_{20}$=−53.7034

$d_{20}$=0.1000

$r_{21}$=13.9402

$d_{21}$=1.3321 $n_{12}$=1.63004 $\nu_{12}$=35.70 $\Delta\theta_{gd}$=0.0002

$r_{22}$=8.5579

非球面係数

（第１３面） $A_4$ =$-0.27966\times10^{-4}$ ， $A_6$ =$-0.87535\times10^{-7}$

$A_8$ =$-0.15668\times10^{-9}$

（第１６面） $A_4$ =$-0.54064\times10^{-4}$ ， $A_6$ =$-0.98203\times10^{-8}$

$A_8$ =$-0.16407\times10^{-9}$

| | | | |
|---|---|---|---|
| f | 9.150 | 25.430 | 71.943 |
| $D_1$ | 1.5000 | 22.8193 | 39.2193 |
| $D_2$ | 39.7158 | 18.3971 | 2.0017 |
| $D_3$ | 7.6660 | 3.2561 | 2.8387 |

$1/(\nu_d)_{1n}$=0.029， $1/(\nu_d)_{1p}$=0.011， $(\Delta\theta_{gd})_{1n}$=0.000

$(\Delta\theta_{gd})_{1p}$=0.062， $1/(\nu_d)_{2n}$=0.017， $1/(\nu_d)_{2p}$=0.048

$(\Delta\theta_{gd})_{2n}$=−0.005, $(\Delta\theta_{gd})_{2p}$=0.036， $1/(\nu_d)_{34n}$ =0.028

$1/(\nu_d)_{34p}$ =0.014， $(\Delta\theta_{gd})_{34n}$ =0.002

$(\Delta\theta_{gd})_{34p}$ =0.027， $(n_e)_{34p}$ =1.571， $\varphi_1/\varphi_W$ =0.131

$|\varphi_2/\varphi_W|$=0.605， $\varphi_3/\varphi_W$ =0.193， $\varphi_4/\varphi_W$ =0.319

$|\varphi_{42}/\varphi_W|$=0.235， $|\varphi_{42}/\varphi_{41}|$=0.484

【００７０】実施例４

f =8.938 〜25.441〜71.978 ， F／2.0

2ω=49.346° 〜17.658° 〜6.204 °

$r_1$ =94.8594

$d_1$ =1.8000 $n_1$ =1.85649 $\nu_1$ =32.28 $\Delta\theta_{gd}$=0.0022

$r_2$ =52.0731

$d_2=5.5535$ $n_2=1.43985$ $\nu_2=94.97$ $\Delta\theta_{gd}=0.0622$
$r_3=-330.4893$
$d_3=0.1000$
$r_4=44.1397$
$d_4=4.1218$ $n_3=1.43985$ $\nu_3=94.97$ $\Delta\theta_{gd}=0.0622$
$r_5=175.9434$
$d_5=0.1000$
$r_6=40.1589$
$d_6=3.9902$ $n_4=1.43985$ $\nu_4=94.97$ $\Delta\theta_{gd}=0.0622$
$r_7=145.1529$
$d_7=D_1$ （可変）
$r_8=609.3378$
$d_8=1.0000$ $n_5=1.62033$ $\nu_5=63.38$ $\Delta\theta_{gd}=0.0070$
$r_9=10.5608$
$d_9=4.4739$
$r_{10}=-44.5113$
$d_{10}=1.0000$ $n_6=1.62033$ $\nu_6=63.38$ $\Delta\theta_{gd}=0.0070$
$r_{11}=35.1888$
$d_{11}=0.1688$
$r_{12}=17.3152$
$d_{12}=0.9992$ $n_7=1.84281$ $\nu_7=21.00$ $\Delta\theta_{gd}=0.0356$
$r_{13}=30.9795$
$d_{13}=D_2$ （可変）
$r_{14}=\infty$（絞り）
$d_{14}=1.1000$
$r_{15}=-17.9714$（非球面）
$d_{15}=1.2101$ $n_8=1.62033$ $\nu_8=63.38$ $\Delta\theta_{gd}=0.0070$
$r_{16}=-28.9343$
$d_{16}=0.1000$
$r_{17}=25.1740$
$d_{17}=1.6914$ $n_9=1.60520$ $\nu_9=65.48$ $\Delta\theta_{gd}=0.0059$
$r_{18}=-67.6119$
$d_{18}=0.8091$ $n_{10}=1.64419$ $\nu_{10}=34.48$ $\Delta\theta_{gd}=0.0016$
$r_{19}=-282.2911$
$d_{19}=D_3$ （可変）
$r_{20}=288.5352$（非球面）
$d_{20}=3.6317$ $n_{11}=1.43985$ $\nu_{11}=94.97$ $\Delta\theta_{gd}=0.0622$
$r_{21}=-21.9444$
$d_{21}=0.1000$
$r_{22}=16.6233$
$d_{22}=1.0000$ $n_{12}=1.69417$ $\nu_{12}=31.08$ $\Delta\theta_{gd}=0.0024$
$r_{23}=9.4208$
$d_{23}=5.0129$ $n_{13}=1.62033$ $\nu_{13}=63.38$ $\Delta\theta_{gd}=0.0070$
$r_{24}=-76.6563$
$d_{24}=0.1000$
$r_{25}=18.2512$
$d_{25}=1.3824$ $n_{14}=1.63004$ $\nu_{14}=35.70$ $\Delta\theta_{gd}=0.0002$
$r_{26}=9.9560$

非球面係数

（第１５面） $A_4=-0.28298\times10^{-4}$ ， $A_6=-0.90598\times10^{-7}$

$A_8$ ＝$-0.75613\times10^{-9}$
（第２０面）$A_4$ ＝$-0.64725\times10^{-4}$ ，$A_6$ ＝$-0.55523\times10^{-7}$
$A_8$ ＝$-0.13010\times10^{-9}$

| | | | |
|---|---|---|---|
| f | 8.938 | 25.441 | 71.978 |
| $D_1$ | 1.5000 | 19.8080 | 33.9524 |
| $D_2$ | 33.4539 | 15.1482 | 1.0044 |
| $D_3$ | 8.7909 | 6.7174 | 13.6922 |

$1/(\nu_d)_{1n}=0.031$，$1/(\nu_d)_{1p}=0.011$，$(\Delta\theta_{gd})_{1n}=0.002$
$(\Delta\theta_{gd})_{1p}=0.062$，$1/(\nu_d)_{2n}=0.016$，$1/(\nu_d)_{2p}=0.048$
$(\Delta\theta_{gd})_{2n}=0.007$，$(\Delta\theta_{gd})_{2p}=0.036$，$1/(\nu_d)_{34n}=0.024$
$1/(\nu_d)_{34p}=0.013$，$(\Delta\theta_{gd})_{34n}=0.003$
$(\Delta\theta_{gd})_{34p}=0.025$，$(n_e)_{34p}=1.555$，$\varphi_1/\varphi_W=0.157$
$|\varphi_2/\varphi_W|=0.629$，$\varphi_3/\varphi_W=0.124$，$\varphi_4/\varphi_W=0.395$
$|\varphi_{42}/\varphi_W|=0.241$，$|\varphi_{42}/\varphi_{41}|=0.435$

【００７１】実施例５

f＝9.304 ～25.457～71.964 ，F／2.0
2ω＝49.471° ～17.846° ～6.262 °
$r_1$ ＝69.3098
$d_1$ ＝1.8000　$n_1$ ＝1.85649　$\nu_1$ ＝32.28　$\Delta\theta_{gd}$＝0.0022
$r_2$ ＝43.4214
$d_2$ ＝5.1245　$n_2$ ＝1.49845　$\nu_2$ ＝81.61　$\Delta\theta_{gd}$＝0.0364
$r_3$ ＝-460.3535
$d_3$ ＝0.1000
$r_4$ ＝37.6226
$d_4$ ＝4.0485　$n_3$ ＝1.43985　$\nu_3$ ＝94.97　$\Delta\theta_{gd}$＝0.0622
$r_5$ ＝185.5159
$d_5$ ＝$D_1$ （可変）
$r_6$ ＝-251.4932
$d_6$ ＝1.0000　$n_4$ ＝1.60548　$\nu_4$ ＝60.70　$\Delta\theta_{gd}$＝-0.0032
$r_7$ ＝12.5818
$d_7$ ＝4.6702
$r_8$ ＝-23.2644
$d_8$ ＝1.0000　$n_5$ ＝1.60548　$\nu_5$ ＝60.70　$\Delta\theta_{gd}$＝-0.0032
$r_9$ ＝75.0852
$d_9$ ＝0.1433
$r_{10}$＝28.1893
$d_{10}$＝2.0000　$n_6$ ＝1.84281　$\nu_6$ ＝21.00　$\Delta\theta_{gd}$＝0.0356
$r_{11}$＝114.7892
$d_{11}$＝$D_2$ （可変）
$r_{12}$＝∞（絞り）
$d_{12}$＝1.1000
$r_{13}$＝16.8270 （非球面）
$d_{13}$＝3.0702　$n_7$ ＝1.57098　$\nu_7$ ＝71.30　$\Delta\theta_{gd}$＝0.0266
$r_{14}$＝-45.9010（非球面）
$d_{14}$＝0.8305
$r_{15}$＝-29.2714
$d_{15}$＝0.8000　$n_8$ ＝1.64419　$\nu_8$ ＝34.48　$\Delta\theta_{gd}$＝0.0016
$r_{16}$＝163.1174
$d_{16}$＝$D_3$ （可変）
$r_{17}$＝38.0917 （非球面）

$d_{17}=2.0000$ $n_9=1.57098$ $\nu_9=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{18}=-35.1200$
$d_{18}=0.1000$
$r_{19}=16.2153$
$d_{19}=1.0000$ $n_{10}=1.80642$ $\nu_{10}=34.97$ $\Delta\theta_{gd}=0.0003$
$r_{20}=10.0172$
$d_{20}=4.2918$ $n_{11}=1.57098$ $\nu_{11}=71.30$ $\Delta\theta_{gd}=0.0266$
$r_{21}=-51.0748$
$d_{21}=0.1000$
$r_{22}=66.1152$
$d_{22}=1.3243$ $n_{12}=1.60548$ $\nu_{12}=60.70$ $\Delta\theta_{gd}=-0.0032$
$r_{23}=10.9915$
非球面係数
（第１３面）$A_4=-0.17119\times10^{-4}$, $A_6=-0.77526\times10^{-7}$
$A_8=-0.61292\times10^{-9}$
（第１４面）$A_4=-0.47301\times10^{-6}$, $A_6=-0.11792\times10^{-6}$
$A_8=-0.11550\times10^{-8}$
（第１７面）$A_4=-0.62049\times10^{-4}$, $A_6=-0.19478\times10^{-7}$
$A_8=-0.39877\times10^{-9}$

| | | | |
|---|---|---|---|
| f | 9.304 | 25.457 | 71.964 |
| $D_1$ | 1.5000 | 22.7213 | 39.7359 |
| $D_2$ | 39.7305 | 18.5090 | 1.5000 |
| $D_3$ | 9.1586 | 5.3246 | 6.9050 |

$1/(\nu_d)_{1n}=0.031$, $1/(\nu_d)_{1p}=0.011$, $(\Delta\theta_{gd})_{1n}=0.002$
$(\Delta\theta_{gd})_{1p}=0.049$, $1/(\nu_d)_{2n}=0.017$, $1/(\nu_d)_{2p}=0.048$
$(\Delta\theta_{gd})_{2n}=-0.003$, $(\Delta\theta_{gd})_{2p}=0.036$, $1/(\nu_d)_{34n}=0.023$
$1/(\nu_d)_{34p}=0.014$, $(\Delta\theta_{gd})_{34n}=-0.000$
$(\Delta\theta_{gd})_{34p}=0.027$, $(n_e)_{34p}=1.571$, $\varphi_1/\varphi_W=0.134$
$|\varphi_2/\varphi_W|=0.598$, $\varphi_3/\varphi_W=0.208$, $\varphi_4/\varphi_W=0.319$
$|\varphi_{42}/\varphi_W|=0.423$, $|\varphi_{42}/\varphi_{41}|=0.686$

【００７２】実施例６

$f=9.015\sim25.458\sim72.000$, $F/2.0$
$2\omega=50.789^\circ\sim18.205^\circ\sim6.307^\circ$
$r_1=140.8301$
$d_1=2.5000$ $n_1=1.81264$ $\nu_1=25.43$ $\Delta\theta_{gd}=0.0165$
$r_2=78.8473$
$d_2=1.0000$
$r_3=106.3821$
$d_3=4.1253$ $n_2=1.43985$ $\nu_2=94.97$ $\Delta\theta_{gd}=0.0622$
$r_4=-248.1614$
$d_4=0.1500$
$r_5=47.1352$
$d_5=5.8436$ $n_3=1.43985$ $\nu_3=94.97$ $\Delta\theta_{gd}=0.0622$
$r_6=620.9556$
$d_6=0.1500$
$r_7=33.7548$
$d_7=4.0084$ $n_4=1.43985$ $\nu_4=94.97$ $\Delta\theta_{gd}=0.0622$
$r_8=60.1247$
$d_8=D_1$ （可変）
$r_9=67.2809$

$d_9=1.5000$　$n_5=1.60548$　$\nu_5=60.70$　$\Delta\theta_{gd}=-0.0032$
$r_{10}=14.5860$
$d_{10}=11.3750$
$r_{11}=-19.6696$
$d_{11}=1.5000$　$n_6=1.60548$　$\nu_6=60.70$　$\Delta\theta_{gd}=-0.0032$
$r_{12}=20.4105$
$d_{12}=0.1500$
$r_{13}=20.6872$
$d_{13}=4.0032$　$n_7=1.84281$　$\nu_7=21.00$　$\Delta\theta_{gd}=0.0356$
$r_{14}=67.4603$
$d_{14}=D_2$　（可変）
$r_{15}=\infty$（絞り）
$r_{16}=155.3540$
$d_{16}=2.5000$　$n_8=1.57098$　$\nu_8=71.30$　$\Delta\theta_{gd}=0.0266$
$r_{17}=-34.2982$
$d_{17}=0.1500$
$r_{18}=14.8060$
$d_{18}=2.5000$　$n_9=1.57098$　$\nu_9=71.30$　$\Delta\theta_{gd}=0.0266$
$r_{19}=-191.1452$
$d_{19}=0.8527$
$r_{20}=-27.3848$
$d_{20}=1.2000$　$n_{10}=1.80642$　$\nu_{10}=34.97$　$\Delta\theta_{gd}=0.0003$
$r_{21}=50.6393$
$d_{21}=D_3$　（可変）
$r_{22}=65.3893$
$d_{22}=2.8000$　$n_{11}=1.57098$　$\nu_{11}=71.30$　$\Delta\theta_{gd}=0.0266$
$r_{23}=-19.3708$
$d_{23}=0.1500$
$r_{24}=20.3762$
$d_{24}=7.0318$　$n_{12}=1.57098$　$\nu_{12}=71.30$　$\Delta\theta_{gd}=0.0266$
$r_{25}=-111.1751$
$d_{25}=0.9735$
$r_{26}=-17.4860$
$d_{26}=1.2000$　$n_{13}=1.85649$　$\nu_{13}=32.28$　$\Delta\theta_{gd}=0.0022$
$r_{27}=-109.6380$

| | | | |
|---|---|---|---|
| f | 9.015 | 25.458 | 72.000 |
| $D_1$ | 1.4000 | 18.9748 | 32.8362 |
| $D_2$ | 33.7987 | 15.3195 | 2.3984 |
| $D_3$ | 7.0203 | 4.9939 | 8.1918 |

$1/(\nu_d)_{1n}=0.039$，$1/(\nu_d)_{1p}=0.011$，$(\Delta\theta_{gd})_{1n}=0.017$
$(\Delta\theta_{gd})_{1p}=0.062$，$1/(\nu_d)_{2n}=0.017$，$1/(\nu_d)_{2p}=0.048$
$(\Delta\theta_{gd})_{2n}=-0.003$, $(\Delta\theta_{gd})_{2p}=0.036$，$1/(\nu_d)_{34n}=0.030$
$1/(\nu_d)_{34p}=0.014$，$(\Delta\theta_{gd})_{34n}=0.001$
$(\Delta\theta_{gd})_{34p}=0.027$，$(n_e)_{34p}=1.571$，$\varphi_1/\varphi_W=0.144$
$|\varphi_2/\varphi_W|=0.695$，$\varphi_3/\varphi_W=0.209$，$\varphi_4/\varphi_W=0.387$
$|\varphi_{42}/\varphi_W|=0.369$，$|\varphi_{42}/\varphi_{41}|=0.596$

ただし$r_1$，$r_2$，…はレンズ各面の曲率半径、$d_1$，$d_2$，…は各レンズの中心肉厚およびレンズ間隔、$n_1$，$n_2$，…は各レンズのe線の屈折率、$\nu_1$，$\nu_2$，…は各レンズのd線のアッベ数である。

【0073】実施例1は図1に示す通りの構成で、物体側から順に、正の屈折力を有しズーミングに際して固定である第1レンズ群と、負の屈折力を有しズーミングに際して光軸上を単調に移動して変倍機能を持つ第2レン

ズ群と、正の屈折力を有しズーミングに際して固定である第３レンズ群と、正の屈折力を有しズーミングに際して光軸上を前後に移動して像面位置の調整を行なう第４レンズ群とからなるレンズ系である。又各レンズ群は、第１レンズ群が物体側から順に、凸面を物体側に向けた負のメニスカスレンズと正の屈折力の強い方の面を物体側に向けた両凸レンズと物体側に凸面を向けた正のメニスカスレンズ２枚とよりなり、第２レンズ群が、物体側より順に、凸面を物体側に向けた負のメニスカスレンズと両凹レンズと物体側に凸面を向けた正のメニスカスレンズとよりなり、第３レンズ群が、物体側より順に、絞りと、像側に凸面を向けた正のメニスカスレンズと、正の屈折力の強い方の面を物体側に向けた両凸レンズと負の屈折力の強い方の面を物体側に向けた両凹レンズとからなり、第４レンズ群が、物体側から順に、正の屈折力の強い方の面を像側に向けた両凸レンズと、正の屈折力の強い方の面を物体側に向けた両凸レンズと、凸面を像側に向けた負のメニスカスレンズとよりなっている。

【００７４】この実施例１のズームレンズの収差状況は、図７，図８，図９に示す通りであって、簡単な構成でありながら極めて高い光学性能を有しており、特に色収差が良好に補正されていることがわかる。

【００７５】実施例２は、図２に示す通りの構成で、実施例１と同様の構成のレンズ系である。図２においてレンズ系と撮像面との間に配置されている平面板は、色フィルターやローパスフィルター等の光学素子を表わしている。

【００７６】この実施例２の収差状況は、図１０，図１１，図１２に示す通りである。

【００７７】実施例３は、図３に示すレンズ構成で、物体側から順に、正の屈折力を有しズーミングに際して固定である第１レンズ群と、負の屈折力を有しズーミングに際して光軸上を単調に移動し変倍機能を有する第２レンズ群と、正の屈折力を有しズーミングに際して固定である第３レンズ群と、正の屈折力を有しズーミングに際して光軸上を前後に移動して像面位置の調整を行なう第４レンズ群とよりなる。又第１レンズ群は、物体側より順に、凸面を物体側に向けた負のメニスカスレンズと正の屈折力の強い方の面を物体側へ向けた両凸レンズとを貼合わせた接合レンズと、物体側に凸面を向けた正のメニスカスレンズとからなり、第２レンズ群は、物体側から順に、負の屈折力の強い方の面を像側に向けた両凹レンズと、両凹レンズと、物体側に凸面を向けた正のメニスカスレンズとからなり、第３レンズ群は、物体側から順に、絞りと、正の屈折力の強い方の面を物体側に向けた両凸レンズと両凹レンズとを貼合わせた接合レンズとよりなり、第４レンズ群は、物体側から順に、凸面を物体側に向けた正のメニスカスレンズと、凸面を物体側に向けた負のメニスカスレンズと両凸レンズとを接合した接合レンズと、凸面を物体側に向けた負のメニスカスレンズとからなり、第１３面と第１６面が、下記の式にて表わされる形状の非球面である。

$$z=\frac{(1/r)y^2}{1+\sqrt{1-(k+1)(y/r)^2}}+a_2y^2+a_4y^4+a_6y^6+a_8y^8+\cdots$$

【００７８】ただし光軸方向をｚ軸方向にとり、光軸に垂直な方向ｙ軸方向にとる。又ｒは非球面の近軸曲率半径、Ｋは円錐定数、$a_i$ は非球面係数である。

【００７９】この実施例３のレンズ系は、非球面を採用することによって、収差補正の自由度を増やし、レンズ系の全長を短くしたもので、実施例１，２が全長が約１２０mmであるのに対して、実施例では光学的全長が約１００mmである。

【００８０】この実施例３の収差状況は、図１３、図１４、図１５に示す通りである。

【００８１】実施例４は、図４に示す通りの構成で物体側より順に、正の屈折力を有しズーミングに際して固定の第１レンズ群と、負の屈折力を有しズーミングに際して光軸上を単調に移動して変倍機能を有する第２レンズ群と、正の屈折力を有しズーミングに際して固定の第３レンズ群と、正の屈折力を有しズーミングに際して光軸上を前後に移動して像面位置の調整を行なう第４レンズ群とからなる。そして第１レンズ群は物体側から順に、凸面を物体側に向けた負のメニスカスレンズと正の屈折力の強い方の面を物体側に向けた両凸レンズとを貼り合わせた接合レンズと、物体側に凸面を向けた正のメニスカスレンズ２枚とからなり、第２レンズ群は、物体側から順に、物体側に凸面を向けた負のメニスカスレンズと、両凸レンズと、物体側に凸面を向けた正のメニスカスレンズとからなり、第３レンズ群は、物体側から順に、絞りと、凸面を像側に向けた負のメニスカスレンズと、正の屈折力の強い方の面を物体側に向けた両凸レンズと凸面を像側に向けた負のメニスカスレンズとを接合した接合レンズとよりなり、第４レンズ群は、物体側から順に、正の屈折力の強い方の面を像側に向けた正レンズと、凸面を物体側に向けた負メニスカスレンズと両凸レンズとを接合した接合レンズと、凸面を物体側に向けた負のメニスカスレンズとよりなり、第１５面と第２０面とが非球面である。

【００８２】この実施例４は、実施例３と同様の仕様であるが、第１レンズ群の正レンズの枚数を増やして特に広角端での歪曲収差の発生を抑制し、これによる第１レンズ群で発生する球面収差やコマ収差を第３レンズ群に負レンズを２枚配置することによって補正するようにした。

【００８３】この実施例４の収差状況は、図１６，図１７，図１８に示す通りである。

【００８４】実施例５は図５に示す通りで、実施例３とは、第３レンズ群が、物体側から順に、絞りと、正の屈折力の強い方の面を物体側に向けた両凸レンズと、負の

屈折力の強い方の面を物体側に向けた両凹レンズとからなり、又第4レンズ群が、物体側から順に、両凸レンズと、凸面を物体側に向けた負のメニスカスレンズと両凸レンズとを貼合わせた接合レンズと、凸面を物体側に向けた負のメニスカスレンズとからなっている点で相違する。又この実施例5では、第13面，第14面，第17面の3面が非球面である。

【0085】この実施例5は、実施例3と比較して、非球面の数を増やしたことにより広角端から望遠端にかけての球面収差、コマ収差、非点収差等の変動が一層少なくなっている。

【0086】実施例5の収差状況は、図19，図20，図21に示す通りである。

【0087】実施例6は、図6に示す構成のレンズ系で、第3レンズ群と第4レンズ群がともにズーミングに際して光軸上を移動して像面位置の補正を行なっている点と、第3レンズ群が、物体側より順に、絞りと、正の屈折力の強い方の面を像側に向けた両凸レンズと、正の屈折力の強い方の面を物体側に向けた両凸レンズと、負の屈折力の強い方の面を物体側に向けた両凹レンズとからなる点において実施例1と相違している。この実施例は、可動群を増やしたことによって収差補正能力を大にし、実施例2ないし4のように非球面を用いることなくレンズ系の全長を実施例1に比較して短くした。

【0088】実施例6の収差状況は、図22，図23，図24に示す通りである。

【0089】本発明において、特許請求の範囲に記載されたレンズ系の他、下記の各項に記載されたものも発明の目的を達成するレンズ系である。

【0090】(1)　特許請求の範囲の請求項1、2又は3に記載されているレンズ系で、第1レンズ群及び第3レンズ群が変倍の際に光軸上に固定であるズームレンズ。

【0091】(2)　前記(1)の項に記載されているレンズ系で、像位置補正のために第4レンズ群が全体として光軸上を移動するズームレンズ。

【0092】(3)　特許請求の範囲の請求項1又は2あるいは前記(1)又は(2)の項に記載されているレンズ系で、下記条件(14)乃至(17)のいずれかを単独で又は複数の組合わせとして満足するズームレンズ。

(14)　$0.10<\varphi_1/\varphi_W<0.21$

(15)　$0.54<|\varphi_2/\varphi_W|<0.76$

(16)　$0.10<\varphi_3/\varphi_W<0.26$

(17)　$0.26<\varphi_4/\varphi_W<0.45$

【0093】(4)　特許請求の範囲の請求項3あるいは前記(1)又は(2)の項に記載されているレンズ系で、第4レンズ群が正の屈折力の第41レンズ群と負の屈折力の第42レンズ群とからなり、下記の条件(18)および／又は条件(19)を満足するズームレンズ。

(18)　$0.19<|\varphi_{42}/\varphi_W|<0.48$

(19)　$0.38<|\varphi_{42}/\varphi_{41}|<0.74$

【0094】(5)　前記(4)の項に記載されているレンズ系で、条件(14)乃至(17)を満足するズームレンズ。

(14)　$0.10<\varphi_1/\varphi_W<0.21$

(15)　$0.54<|\varphi_2/\varphi_W|<0.76$

(16)　$0.10<\varphi_3/\varphi_W<0.26$

(17)　$0.26<\varphi_4/\varphi_W<0.45$

【0095】(6)　特許請求の範囲の請求項1あるいは前記(1)又は(2)に記載されているレンズ系で、下記の条件(4)乃至(7)を満足するズームレンズ。

(4)　$0.014<1/(\nu_d)_{2n}<0.017$

(5)　$-0.01<(\Delta\theta_{gd})_{2n}<0.01$

(6)　$0.030<1/(\nu_d)_{2p}$

(7)　$0.015<(\Delta\theta_{gd})_{2p}$

【0096】(7)　特許請求の範囲の請求項1又は2あるいは前記(1)、(2)又は(4)の項に記載されているレンズ系で、下記の条件(8)乃至(11)を満足するズームレンズ。

(8)　$0.020<1/(\nu_d)_{34n}<0.033$

(9)　$-0.01<(\Delta\theta_{gd})_{34n}<0.01$

(10)　$0<1/(\nu_d)_{34p}<0.0166$

(11)　$0.02<(\Delta\theta_{gd})_{34p}$

【0097】

【発明の効果】本発明のズームレンズは、比較的簡単なズーム構成でありながら、撮像管や固体撮像素子等を用いた電子カメラ特に近年の高精細画像を取込む用途に適した画素数の多い撮像素子を用いた電子カメラに最適な高い光学性能で小型なレンズ系になし得たものである。

【図面の簡単な説明】

【図1】本発明の実施例1の構成を示す図

【図2】本発明の実施例2の構成を示す図

【図3】本発明の実施例3の構成を示す図

【図4】本発明の実施例4の構成を示す図

【図5】本発明の実施例5の構成を示す図

【図6】本発明の実施例6の構成を示す図

【図7】本発明の実施例1の広角端における収差曲線図

【図8】本発明の実施例1の中間焦点距離における収差曲線図

【図9】本発明の実施例1の望遠端における収差曲線図

【図10】本発明の実施例2の広角端における収差曲線図

【図11】本発明の実施例2の中間焦点距離における収差曲線図

【図12】本発明の実施例2の望遠端における収差曲線図

【図13】本発明の実施例3の広角端における収差曲線

図

【図１４】本発明の実施例３の中間焦点距離における収差曲線図

【図１５】本発明の実施例３の望遠端における収差曲線図

【図１６】本発明の実施例４の広角端における収差曲線図

【図１７】本発明の実施例４の中間焦点距離における収差曲線図

【図１８】本発明の実施例４の望遠端における収差曲線図

【図１９】本発明の実施例５の広角端における収差曲線図

【図２０】本発明の実施例５の中間焦点距離における収差曲線図

【図２１】本発明の実施例５の望遠端における収差曲線図

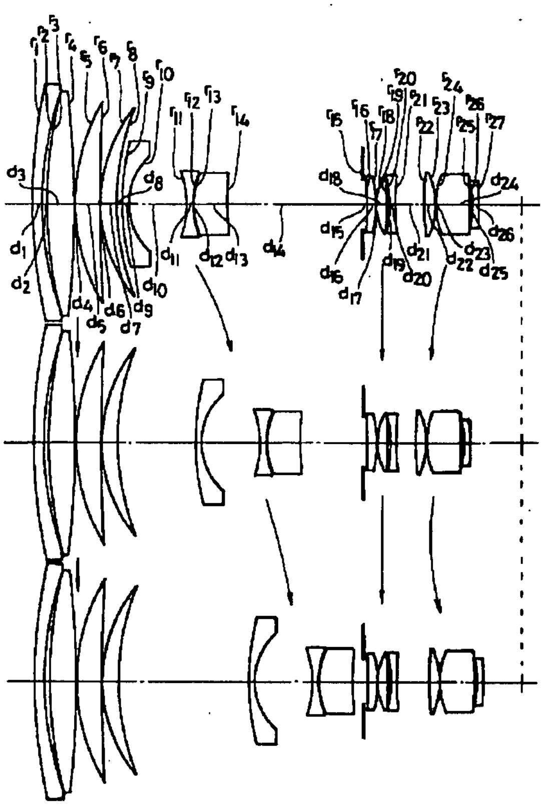
【図２２】本発明の実施例６の広角端における収差曲線図

【図２３】本発明の実施例６の中間焦点距離における収差曲線図

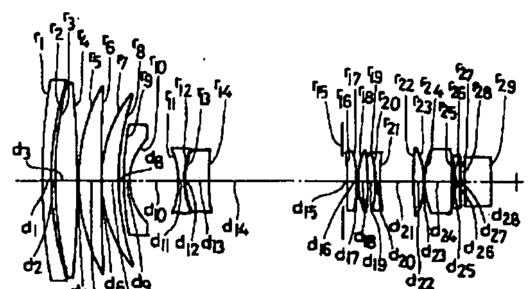
【図２４】本発明の実施例６の望遠端における収差曲線図

【図２５】$\theta_{gd}-\nu_d$ グラフ

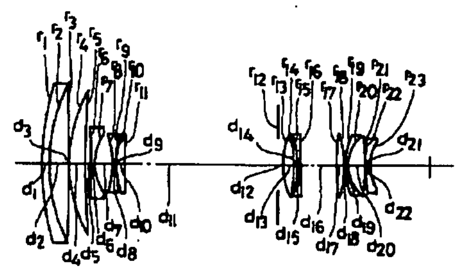
【図1】



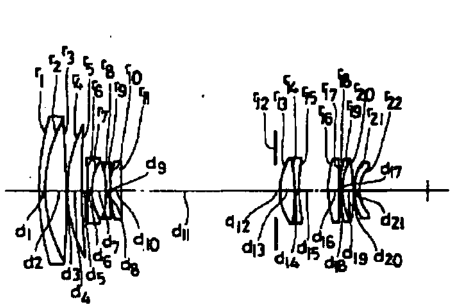
【図2】



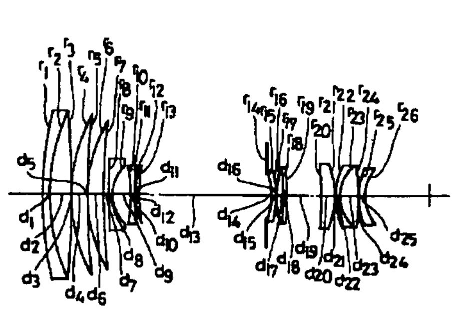
【図5】



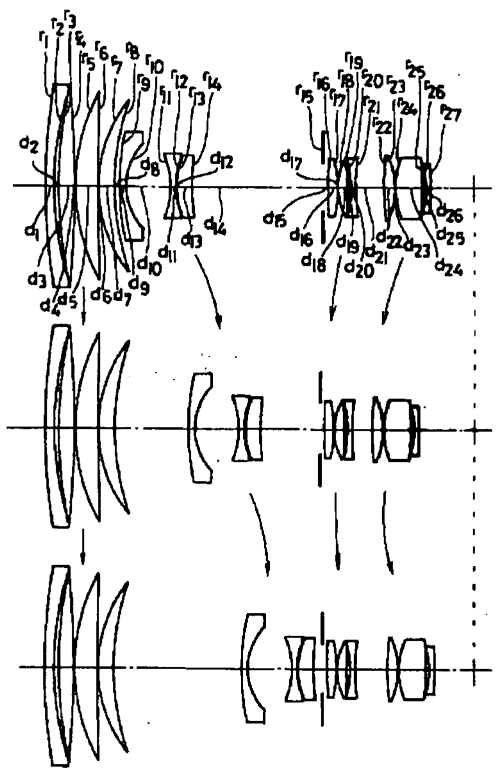
【図3】



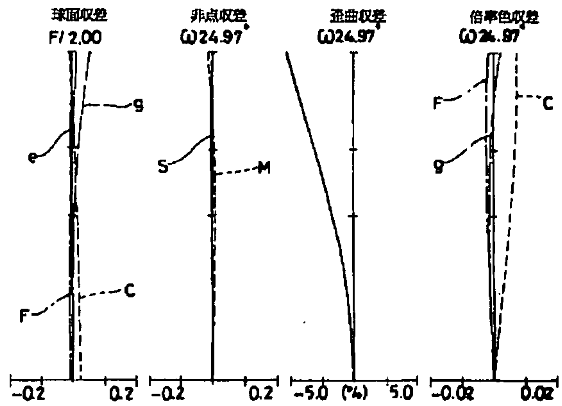
【図4】



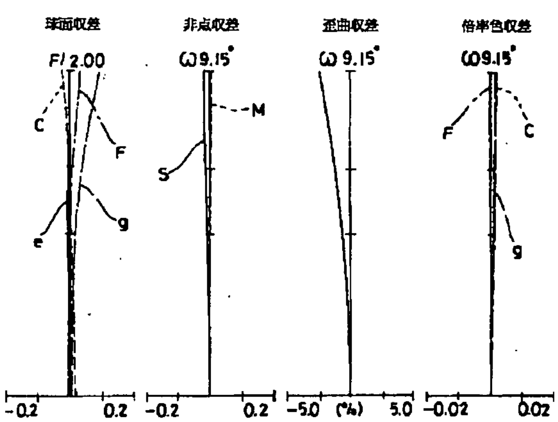
【図6】



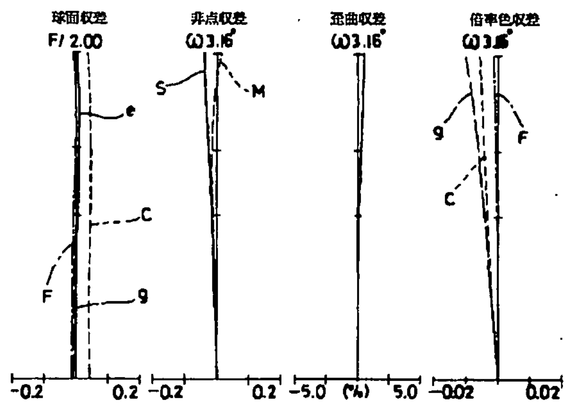

【図7】



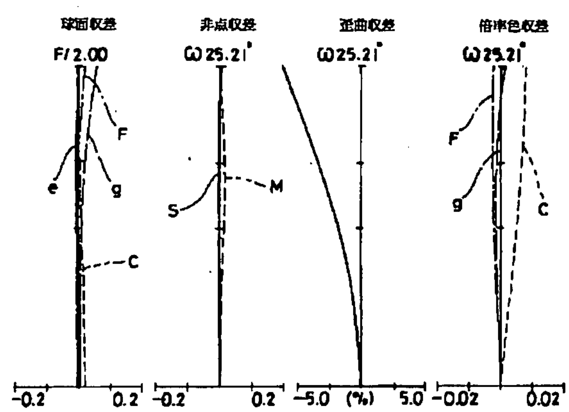

【図8】



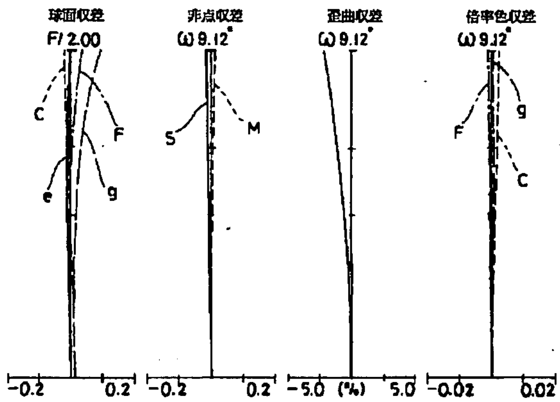

【図9】



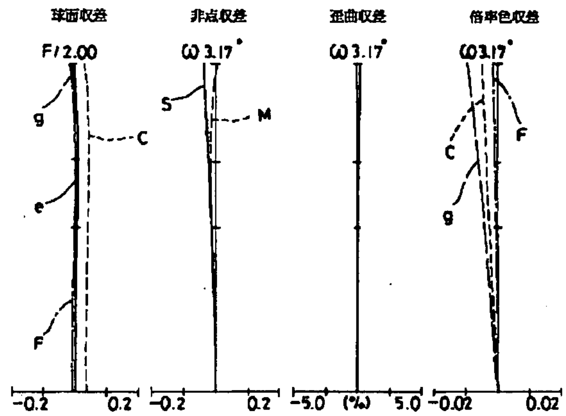

【図10】



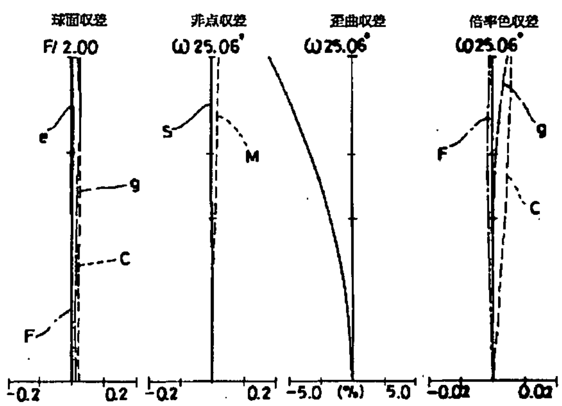
【図１１】



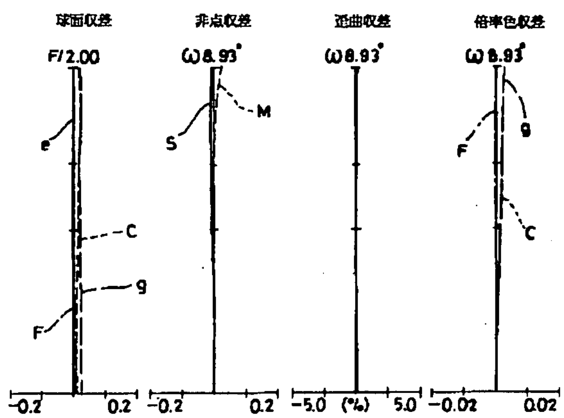

【図１２】



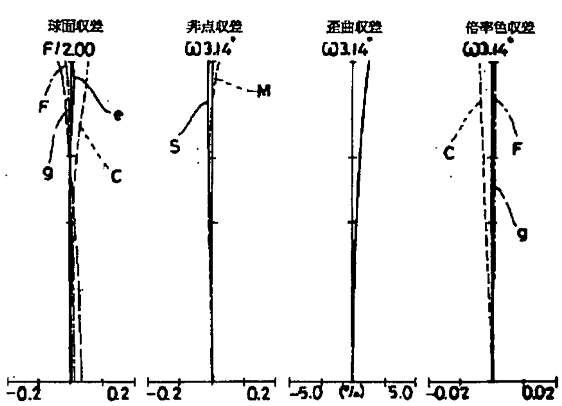

【図１３】



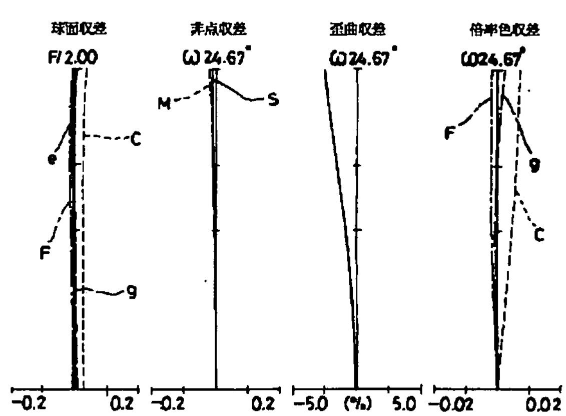

【図１４】



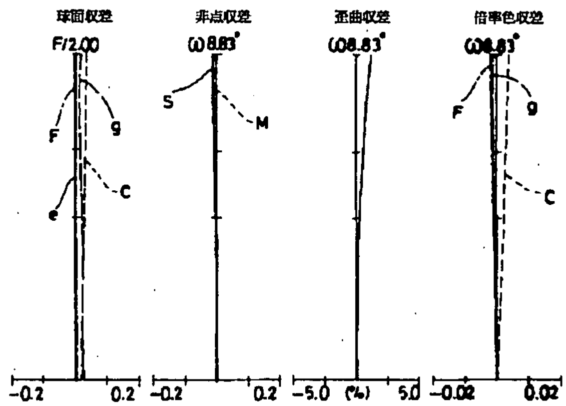

【図１５】



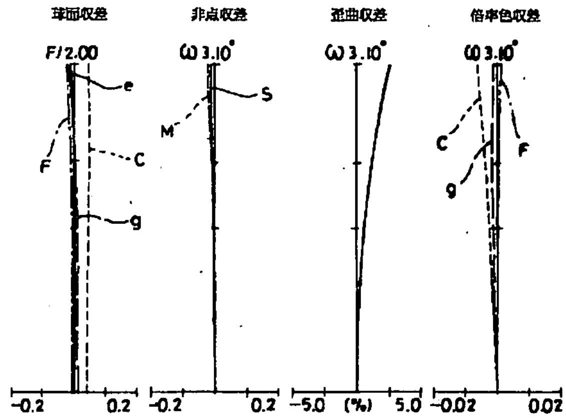

【図１６】



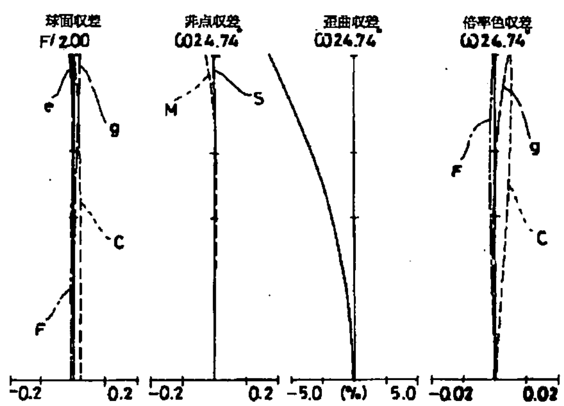
【図１７】



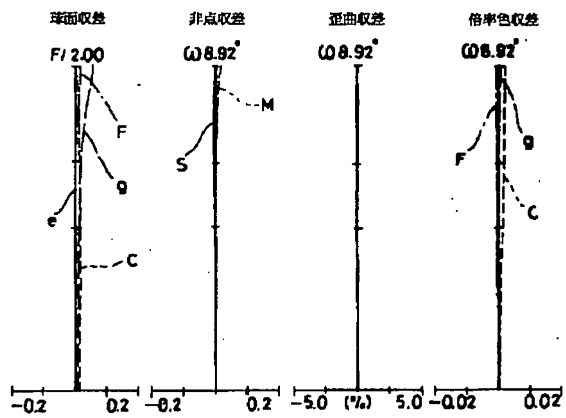

【図１８】



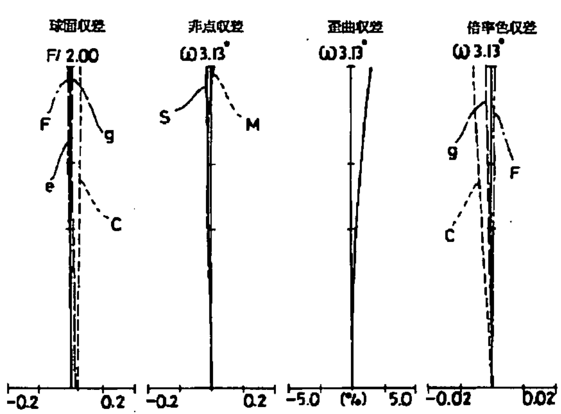

【図１９】



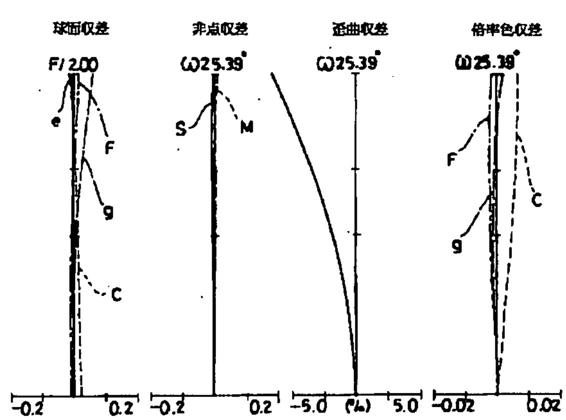

【図２０】



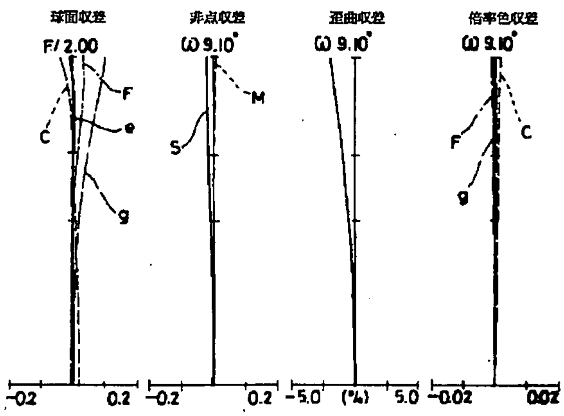

【図２１】



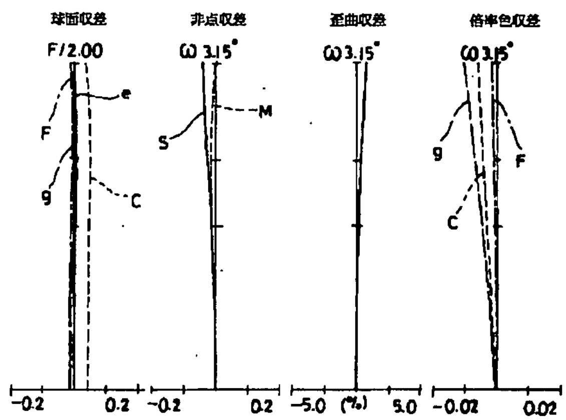

【図２２】



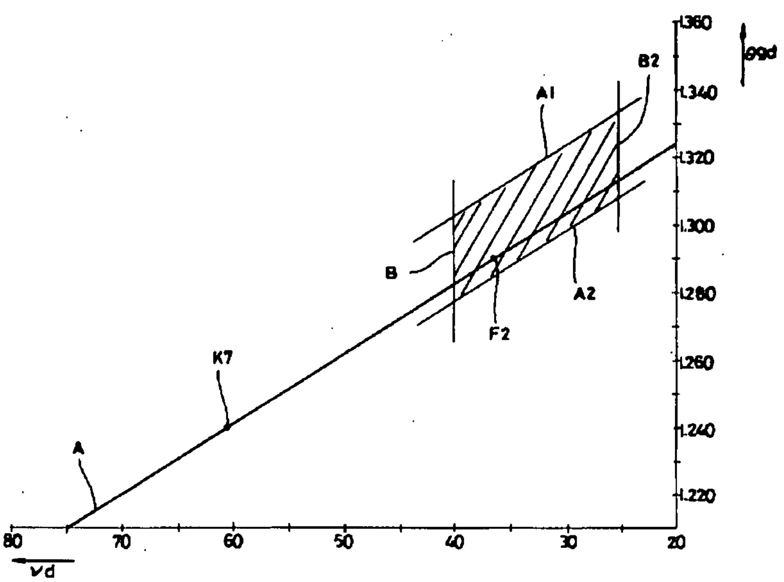
【図２３】


球面収差
非点収差
歪曲収差
倍率色収差
F/2.00
ω 9.10°
F
C
e
g
S
M
-0.2
0.2
-5.0
(%)
5.0
-0.02
0.02

【図２４】


球面収差
非点収差
歪曲収差
倍率色収差
F/2.00
ω 3.15°
e
F
g
C
S
M
-0.2
0.2
-5.0
(%)
5.0
-0.02
0.02

【図２５】


θgd
νd
A1
A2
B
B2
F2
K7
A
1.360
1.340
1.320
1.300
1.280
1.260
1.240
1.220
80
70
60
50
40
30
20